

**JOURNAL OF THE  
SOCIETY OF  
MOTION PICTURE  
AND  
TELEVISION  
ENGINEERS**



**Progress Committee Report**

**Reflectance of Human Flesh**

**Televising a Symphony Orchestra**

**Television Transmission Echoes**

**Rocket Motor Research**

**High-Speed Photography**

**American Standards**

**74th Semiannual Convention • October 5-9 • New York**

**MAY 1953**

# Society of Motion Picture and Television Engineers

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# Progress Committee Report

By GEORGE R. GROVES, Committee Chairman

THE YEAR 1952 will be marked as a milestone in the history of motion-picture production and presentation. At a time when the motion-picture industry was beset with depressing reports of poor box-office receipts from the best product that the industry could produce, there appeared on the screen two epoch-making presentations that have revitalized the motion-picture business. The reference is, of course, to the presentation of Cinerama in New York and the showing of *Bwana Devil*, the 3-D production of Arch Oboler, in Los Angeles. In compiling the Progress Report for 1952 it would seem logical, therefore, that these two presentations should be reported upon first.

## Cinerama

Cinerama, the invention of Fred Waller, opened in New York September 30, 1952.<sup>1</sup> This spectacular presentation reproduces a picture 145° wide and 55° high on a 25 × 50-ft screen, using three complete projection equipments, and seven magnetic tracks on 35mm film. The seven magnetic tracks are reproduced through six channels to drive six sets of loudspeakers — five behind the

screen and one set around the auditorium — giving an auditory perspective effect. The seventh track is used as a control track. The original tracks were re-recorded by Reeves on magnetic stock and all re-recording and reproducing is accomplished on Westrex RA-1506-type film drive mechanisms using special seven-track heads. Equalization is designed to produce flat response to 12 kc from film running at the rate of 39 frames/sec. Synchronous motors are used to drive the three projectors and the sound reproducer with a synchronous control system operating between machines. The control is quite positive and will pull the projectors into step over a range of approximately twelve frames.

## Stereoscopic Productions

Prior to 1952, demonstrations of three-dimensional films in this country were regarded as a novelty. On November 26, 1952, Natural Vision's presentation of their Polaroid three-dimensional picture, *Bwana Devil*,<sup>2</sup> at the Paramount Theater in Hollywood and the Paramount Theater in Los Angeles, removed the 3-D picture from the novelty class to the status of an extremely important form of motion-picture entertainment. Since that time this picture has had quite extensive release throughout the United States and its phenomenal success has resulted in many of the Hollywood producers plunging into 3-D production.

By the end of 1952, those concerned with the production of motion-picture

Submitted March 26, 1953, by George R. Groves, Committee Chairman.

Note: An addendum to this report will be published in the June *Journal*, prepared from material submitted in German by committee member Leo Busch, received too late to permit publication in this issue.

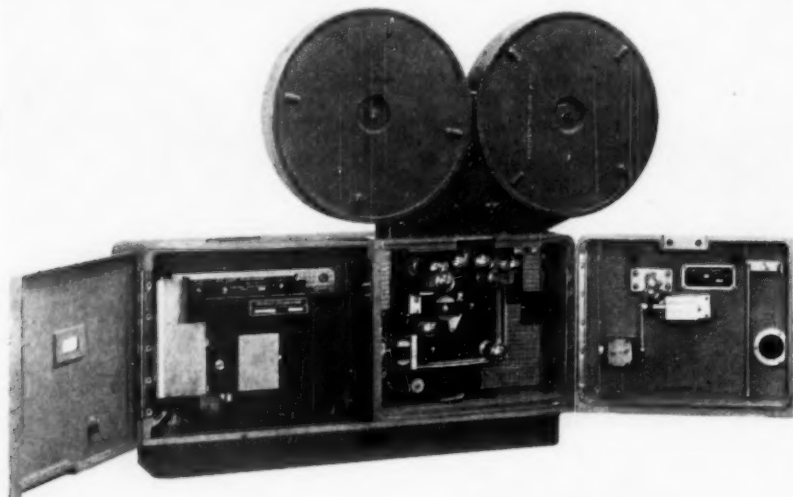


Fig. 1. Westrex Photomagnetic Recorder.

entertainment seemed to be divided into two camps—those favoring the wide-screen panoramic-vision type of presentation as typified by Cinerama and those favoring three-dimensional pictures requiring the use of Polaroid viewers for true stereoscopic effect. The Twentieth Century-Fox Studios widely publicized their CinemaScope type of production in which a wide field of vision is accomplished in the camera by means of an auxiliary shooting lens designed to compress the angle of view in the horizontal plane, and this in turn is expanded by an auxiliary lens system in projection. The first production to be shot by this company with this system is to be *The Robe*, which will also be accompanied by stereophonic sound.

With the emergence of the modern 3-D film into general commercial circulation, rapid strides were made in England toward perfecting its techniques of production and exhibition. The leading role was played by Stereo Techniques, Ltd., staffed by the personnel who had

devised the 3-D film program for the Festival of Britain.<sup>3</sup> During the year, this company leased its films for commercial showing in Great Britain, France, Germany, Holland, Belgium, Sweden and Denmark, thus gaining invaluable knowledge of audience reaction and projection techniques.<sup>4,5</sup> Special synchronizing gear was also developed by this company for apprising the projectionist of errors of synchronism between the two bands of film, and enabling him to correct them without stopping the machines. With the rapid growth of 3-D production, new camera designs were embarked on, based on an extended analysis of stereoscopic transmission theory.<sup>6</sup> Progress was also made during the year by H. Dewhurst, A.R.C.S., on a single film system with left and right images rotated through 90° by mirrors or prisms,<sup>7</sup> as in the prewar Zeiss Ikon system. L. Dudley also claimed advances both in single-film stereo and lenticular projection, but without disclosing details.

In France renewed efforts were made by inventors to dispense with viewing glasses, and effect image separation at the screen.

The number of 3-D productions which have been planned virtually overnight and distribution and exhibition of these productions has presented complicated and very serious problems of standardization. Since three-dimensional pictures of the Polaroid-viewing type of necessity require two projectors to be running simultaneously, the problem of reel sizes for the minimum number of change-overs and intermissions becomes very acute. It has been necessary to set up committees to establish at least temporary standards for reel sizes, screen sizes, screen types, projector interlocking mechanisms, designation of right and left films, allocation of sound track to a specific film, and improved light sources. The problem of light loss in projection through Polaroid filters is very acute. Approximately 60% of the light is lost.

#### Sound Recording

Magnetic recording became the established medium for original dialogue and music recordings throughout the motion-picture industry in 1952. Those studios which attempted to extend the use of magnetic recordings to the motion picture editor's work found it necessary to provide some form of visual modulation aid. One generally accepted method for doing this is through the use of a combination photographic-magnetic sound track. As this would imply, the film carries both a photographic sound track of either the negative-positive or direct-positive types and a magnetic sound track recorded on a narrow strip or stripe of magnetic material located on the opposite edge of the film. This has naturally increased the popularity and demand for the so-called Magna-Stripe film, and for dual photomagnetic recording equipment.<sup>10</sup> The Westrex Photomagnetic Recorder illustrated in Fig. 1 records collinear 200-mil push-pull

direct-positive variable-area and magnetic tracks. Such a track combines the advantages of a photographic track for editing and the superior quality of magnetic track for re-recording.

Another type of visual aid has been provided by the "Sound Scribing" method. One form of this consists of an ink trace of the sound modulation scribed on the film base adjacent to the magnetic track.

Another method perfected by the Glen Glenn Studios in Hollywood, involves actually engraving a variable-area type track in an auxiliary or loading stripe by means of a diamond cutter closely resembling a "hill and dale" disk recorder. This engraved track can be clearly seen and reproduced on a 35mm moviola. This method has been used in the production of the popular television shows *I Love Lucy* and *Our Miss Brooks*, produced by Desilu Productions.

Those studios which do not use the visual aids mentioned above provide the editor with a photographic copy of the original magnetic recording. Methods for recording both variable area and variable density directly from magnetic film for intra-studio use were described.<sup>12,13</sup> The transfer from magnetic to direct positive is the most economical. This method is used in the Warner Bros. Sound Department, where the direct-positive editor's track is also used as a re-recording track after having been given a hard protective coating by the Protising Process.

A cross-modulation compensator was introduced by RCA in 1952 for use in the production of direct-positive variable-area recordings. This device is introduced in the audio transmission system of a recording channel and will counteract cross-modulation products produced by other parts of the system, such as the emulsion in a photographic variable-area track. In general, this device generates distortion products equal in amplitude and opposite in phase to those contributed by the film emulsion, so that when

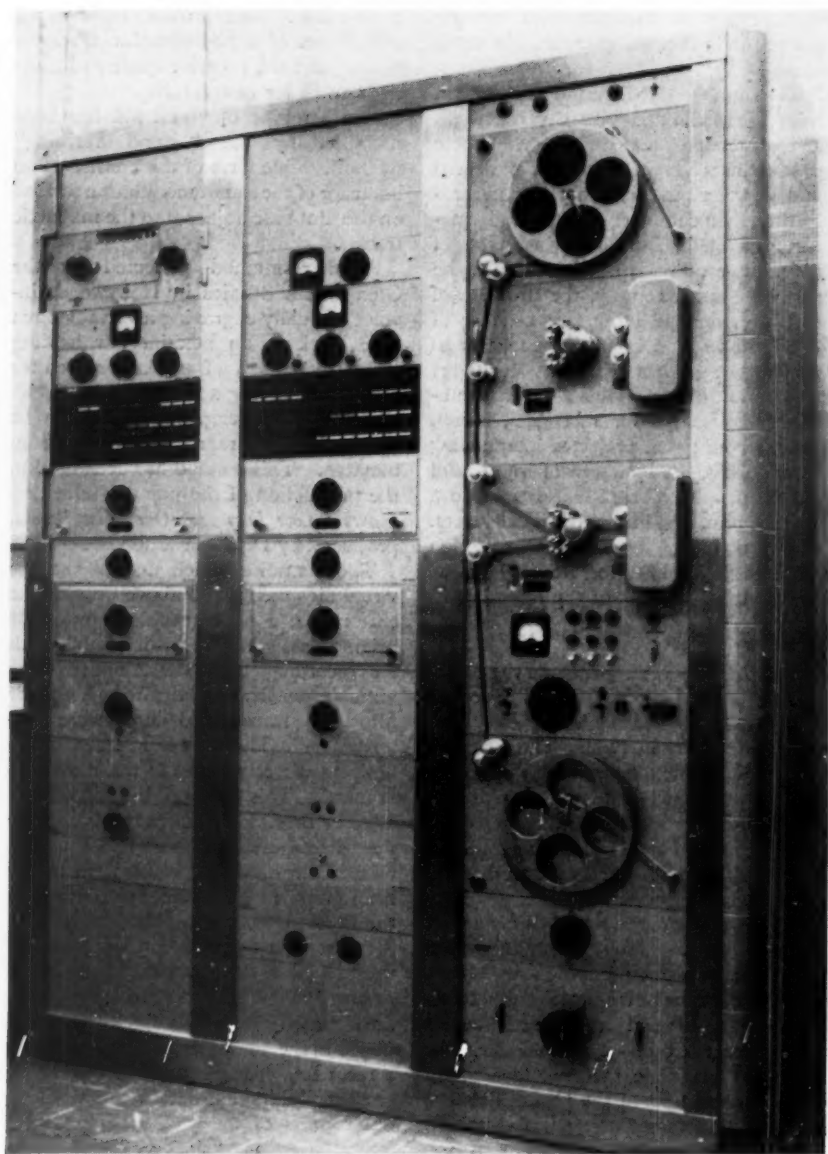


Fig. 2. RCA Magnetic Transfer Machine.

the two distortion products are combined, they will cancel each other. This results in reproduced sound free from cross-modulation distortion due to image spread. It is now possible to produce such recordings at a density of 1.80 with a cross-modulation cancellation of 40 db as compared to a density of 1.0 without the use of this device.

The magnetic transfer machine, illustrated in Fig. 2, was also developed by RCA and placed in operation at the Warner Bros. Studios during 1952. This reproducing machine was developed specifically for transferring magnetic material such as production dialogue and music scoring to another record. It is capable of reproducing both 17½-mm single-track film operating at 45 fpm and 35mm three-track film operating at 90 fpm. A unique feature is the ability to transport film from reel to reel at four times the respective operating speeds without removing the films from their driving sprockets. This makes for rapid selection of "ok'd" takes which are to be transferred to another record. Additionally, high-speed rewinding directly from reel to reel at approximately ten times the normal operating speeds is provided. The savings in operating cost due to the use of this equipment make it a worthy contribution to the art of sound-film recording.

During 1952, the Paramount Sound Department built and placed in use a magnetic-to-magnetic transfer reproducer-recorder, designed to speed up the transfer of sound effects and short dialogue sequences for editing.

The film is transported on plastic belts which also hold the film "wrapped" on the reproduce and record heads. Sprocketless and requiring no loading leader, the films are up to recording speed in a small fraction of a second. The reproduce and record belts are driven from a common shaft causing starting flutter to be comparative and not heard in subsequent reproduction.

The transferred film is in linear syn-

chronism with the original. Sprocket-hole pitch variations may alter exact synchronism but within the limits for this type of service. Loading is simple and encourages the use of film "short-ends."

A similar device is in use at Ryder 16mm Services for the re-recording reproduction of sound effects loops. Quick loading and unloading of loops is possible *while running*.

The three-track recording machines which several studios have installed have now, by coincidence, become natural instruments for stereophonic recordings, which are being intensely studied. Wide use of stereophonic recordings for large-screen and stereoscopic shows is in prospect.

Now that the design and application of magnetic recorders has reached mature stage, more thought is being directed toward study of the nature of the magnetic process itself, particularly with a view toward standardization. The necessity for standardization arises, of course, from the fact that all products should reproduce on standard equipment, or at least deviations from standard should be under control. It is generally agreed that recordings should be laid down in such a way that they may at any future time reproduce interchangeably with future products regardless of improvements in magnetic materials and techniques. Therefore, a "standard reproducer" should be defined and means provided for its calibration. This is not a simple task in the case of magnetic recording because the characteristic is controlled by the respective recording and reproducing gaps as well as the magnetic material of the track itself, and measurement of these elements is difficult and, in general, requires dynamic measurements.

Many groups have been working at the problem of film calibration during the year. These include equipment manufacturers, the JCIC, the SMPTE Committee on Sound and the CCIR (International Radio Consultative Committee). Through the latter, the "long-

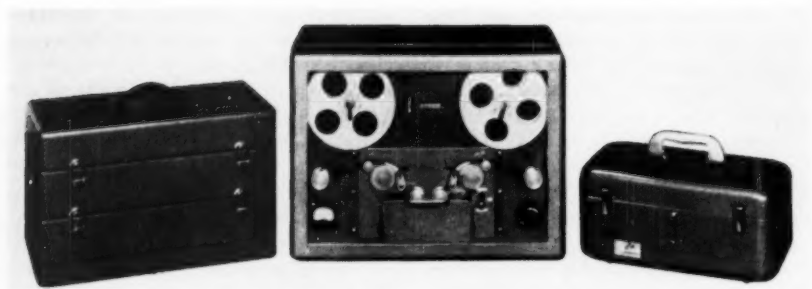


Fig. 3. RCA Portable Magnetic Recording Channel.



Fig. 4. Close-up view of the principal operating controls and microphone of the Bell & Howell Filmosound 202 16mm Optical-Magnetic Recording Projector.

gap"<sup>14</sup> and "short-gap"<sup>15</sup> methods of calibration have been disclosed and are being tested by the various groups. Contributions to the subject of magnetic recording available during the year were discussions of "recording demagnetization"<sup>16</sup> and an evaluation of losses due to

space between magnetic heads and recording media.<sup>17</sup>

A test film was developed which makes it possible to check the azimuth of a magnetic head without disturbing any of the azimuth adjustments. It not only checks whether or not the azimuth is cor-

rect, but shows in which direction the azimuth must be rotated if it needs correction. Such a test film is now being proposed under ASA standards and identified as SMPTE 512 MPRC: 58.583B SO 12.2 6 Nov. 1, 1952.

Among new equipments offered to the industry in 1952 may be listed the Westrex RA-1511-A converter which is a nonrotating device for the conversion of single-phase 115-v power to a three-phase 230-v form for the synchronous operation of camera, sound recorders and other film-pulling mechanisms associated with the production of motion pictures.<sup>11</sup>

A new portable magnetic recording channel (Fig. 3) was made available by RCA, designed primarily for 17½mm film. By operating at 45 fpm a considerable economy in film cost is realized and the size and weight of the recorder are reduced. The recorder is also adaptable for 16mm and 35mm film. A new amplifier system utilizing miniature tubes and small components is provided as part of the equipment.

In an effort to develop lighter weight and more flexible sound-recording equipment, the Telefunken Uni-Directional condenser microphone was repackaged by Paramount into a unit, including bail, weighing only 6 oz. The basic condenser element has been built into a 2½-in. diameter screen sphere, which also houses a subminiature tube. This has made possible the use of a lightweight boom having 40% of the weight of a typical boom, and also an ultra-light-weight fishpole having not only "panning" facilities but also "great circle" movement of the microphone. Six pictures have been recorded with these microphones.

*Sound Recording in England.* It was not until 1952 that magnetic sound recording was adopted by the British on any considerable scale. This was due to the general policy of restraint in capital expenditure and the lack of suitable studio equipment.

As a first step in the change-over from photographic to magnetic recording, both RCA and Westrex made available conversion kits by means of which existing photographic recorders could be operated as dual-purpose, photographic and magnetic machines. Later in the year, RCA, Westrex and Gaumont-Kalee introduced recording, re-recording and portable equipments designed specifically for magnetic service. In general, the standard speed of 90 fpm has been adhered to in English equipments.

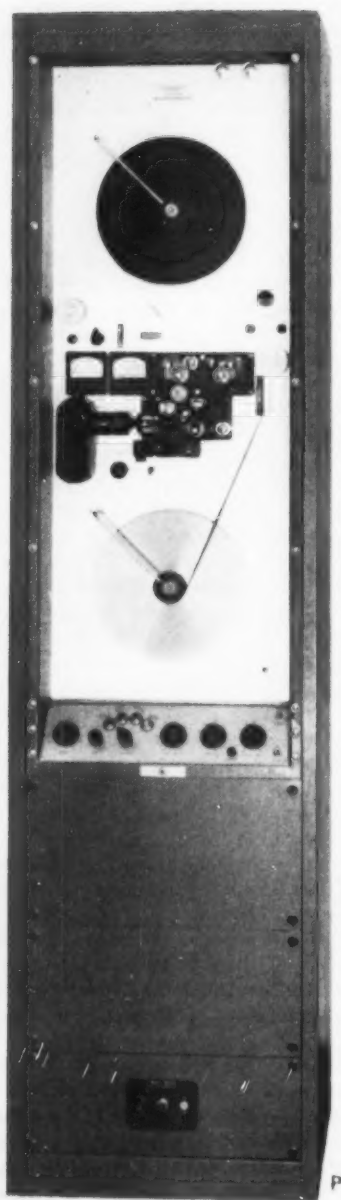
A number of ¼-in. magnetic tape recorders were available in 1952. The Leever-Rich Syncropulse recorder can be operated synchronously with the picture camera. High-quality nonsynchronous equipments were manufactured by Leever-Rich, Philips and E.M.I.

35mm, 17½mm and 16mm perforated magnetic film were made available by Pyral and Kodak (both of French manufacture) and Gevaert (Belgian manufacture), while Minnesota Mining Corp. announced the manufacture of a similar range in England.

#### 16mm

During 1952 it was necessary to increase the plant capacity of most of the 16mm processing laboratories in the country to meet the increased demand for their product by the producers of films for television, television stations, industrial organizations and educational institutions. The conversion of silent 16mm pictures to sound pictures and the production of new sound 16mm pictures has been made possible and accelerated by the application of magnetic striping to 16mm film stock.

In 1952, the Bell & Howell Company announced its Sound Stripe process for applying a magnetic stripe to the edge of 16mm film and its design of a combination optical magnetic recording 16mm projector (Fig. 4) which would record and play on film having perforations on both edges as well as on the conventional sound film perforated on one edge only.



**Fig. 5. Westrex RA-1509-A Recorder-Reproducer.**

The Westrex RA-1509-A Recorder-Reproducer (Fig. 5), containing magnetic recording and magnetic and photographic reproducing channels, also made a material contribution toward raising the standard of 16mm quality during 1952.

The introduction of Sonotrack magnetic striping for 16mm processed sound film was announced to the trade by the Eastman Kodak Company in July 1952. The process was described in detail in a paper presented at the SMPTE Fall Convention, but has not yet been published.

Paillard Products, Inc., of New York put on the market a 16mm stereo attachment for camera and projector designed by Paillard, S.A. of Switzerland. In its camera form, this attachment consists of two  $f/2.8$  fixed-focus lenses set with their axes 64 mm apart and forming two erect side-by-side images on a single 16mm frame. The optical axes are parallel and the interocular separation is fixed.<sup>8,9</sup> The stereo-taking lens attachment is manufactured, at the present time, for the Bolex 16mm Camera only.

During 1952, Technicolor changed the sound-track specifications for their Type B, or imbibition 16mm prints, from a blue dye track to a silver track having the same characteristics as a black-and-white print. This provides the best possible sound printing from re-recorded negatives, and the advantage of quantity production which the Type B process affords.

In the application of 16mm films for educational purposes all leaders appear to be interested but have not been able to determine to what extent magnetic recording and reproducing facilities can be used. A few universities are planning to produce their own motion pictures on an experimental basis. Certain Government agencies are using magnetic projectors and magnetic striped prints in their foreign aid programs. The year 1952 saw a greater production of teaching films, especially designed for class-

room application, than any preceding year.

### Film Processing Laboratories

The impact of stereoscopic photography was strongly felt by the film processing laboratories inasmuch as most of the systems required two films which had to be processed and printed with special consideration.

The initial 3-D film, *Bwana Devil*, was processed by Pathé Laboratory and was printed on Eastman Color Print film from an Ansco negative — the first occasion wherein the crossover had been successfully attempted. Printing equipment was altered to insure stability of the dual images on the screen.

Warner Bros. was preparing its laboratory facilities for 3-D by the year end also, having successfully processed a number of productions in Eastman Color during 1952.

M-G-M laboratory, having processed one Ansco Negative feature in 1952, undertook expansion of its color developing machine capacity. A new design is being incorporated in the unit which will be in service early in 1953.

General Film Laboratory constructed a new laboratory building to be used exclusively for 16mm processing and printing. Several cutting rooms were also added in this new facility. Operation of the new plant is anticipated by Spring 1953. 35mm color processing facilities were available at this laboratory to render prints on either Eastman Color or du Pont during 1952.

Unicorn Laboratories was a new entry into the independent laboratory field, having taken over the former Paramount facility. This company is planning to offer 16mm and 35mm service. Pathé Laboratory also added a 16mm plant to cope with the television demand. This equipment can also accommodate the negative-positive color processes when available in 16mm. New cutting and projection rooms were also a part of the expansion program.

The first 35mm Eastman Color prints were made from 16mm Kodachrome (both daylight and commercial) by Hollywood Film Effects in cooperation with Pathé Laboratory during the past year.

### Color

The year 1952 was a great year for productions in color. In three of the major studios, motion pictures in color outnumbered those in black-and-white. For interest, a survey was taken to determine what percentage of the total production was in color.

These percentages for several of the studios are as follows: Columbia, 30%; Fox, 55%; M-G-M, 47%; Paramount, 65%; RKO, 35%; Universal, 50%; and Warner Brothers, 70%.

At M-G-M black-and-white methods are applied as much as possible in its color laboratory. Over 500 release prints were made of *Wild North*, an Ansco Negative-Positive product, with losses reported to be no greater than black-and-white. The release was made on unchanged Model E printing machines with color filters being combined with the travelling matte.

Warner Brothers produced five feature-length pictures in its new Warner Color process — an Eastman Color Negative-Positive process.

Consolidated Film Industries converted its Trucolor process from one requiring sequential printing from separation negatives to one whereby Eastman Color Negative is printed directly onto Eastman Color Positive in a continuous printer. The printer has three separate light sources and three narrow-band filters with the light intensity being changed by a variable-area matte. At its Fort Lee laboratory, Consolidated reports considerable progress in making 16mm Ansco Color Positive prints from 16mm original Kodachrome by means of a special Ansco intermediate color negative.

In England, preparations were made

for the processing of Tripack color films, the best known of which are the Eastman Color, Ferranicolor and Gevacolor. At the present time all these films have to be imported and manufacture of 35mm integral Tripack motion picture film seems unlikely in this country before 1954. It is reported that Gevacolor was used for a full-length feature film in Australia with good results, considering that an exposed footage had to be flown to London for processing.

### Television Broadcasting

Of great significance in the United States was the part played in 1952 by television in the Democratic and Republican National Presidential Conventions, both of which were broadcast to a nationwide audience.<sup>19,20</sup>

Broadcasting facilities were generally improved throughout the United States.<sup>21-24</sup> There was a noticeable improvement in programs presented, due particularly to improvements in equipment.<sup>25-28</sup> The development of flying spot scanners was a noteworthy step forward during 1952,<sup>29-31</sup> and these were demonstrated for the continuous scanning of 16mm motion-picture film. Manufacturers planned to place commercial versions of these scanners on the market the following year, 1953.

The big news in television during 1952 was, of course, the lifting of the "freeze" and the start of new station construction. It had been four years since any construction permits had been granted by the FCC. Meanwhile, television sets have been selling at an increasing rate until there is now nearly one set for every two homes in America. Many cities still had only one television station, and as the set saturation went up so did the rates and so did the profits. Many of the small local stations reached the end of the year with larger net profits than the networks were able to show.

With the lifting of the "freeze," new television broadcasting stations began to make their appearance. The Federal

Communications Commission, in adopting its Sixth Report and Order on allocations in April, 1952, made it possible to allocate additional channels for VHF broadcasting, as well as to "open up" the 472-890 mc UHF band. This made possible the ultimate addition of some 2000 new television stations.<sup>34</sup>

The "freeze" was lifted in April, in June permits began to be granted once more and by year's end another two dozen stations were operating, and two or three new ones were being added to the list each week. Many of these stations are in the UHF channels, using entirely different transmission equipment and facing new propagation problems which had only been faced experimentally before.

One tenth of all the new channel allocations were reserved for educational, noncommercial use. Only about 15% of these 242 channels have been spoken for, and the industry is hoping that after the expiration of a year, as the FCC has repeatedly warned the educators, most of them will be turned back to commercial purposes to accommodate applicants who were previously unsuccessful in obtaining regular commercial channels. Some 15 or 20 states have made plans for statewide networks of educational stations, and 10 or 15 educational stations are expected to go on the air during the next year.

With the tremendous growth of television stations, the networks stations in New York have, during the latter half of the year, experienced a considerable decrease in production activity. There is a very marked trend toward film and Hollywood, and away from live production and New York. Each of the networks has reduced staff and closed studios (except DuMont which has just opened a large new five-studio building). Many of the top television programs, especially the dramatic shows, are now seen on film, either run locally from 16mm prints at the individual stations, at whatever time is convenient, or fed over a

network hook-up, projected in New York from 35mm prints. Most production of commercial films, spots, etc., for network use is in 35mm, although the small stations rarely are equipped with anything other than 16mm projection equipment.

There was development during 1952 in rear-view projection techniques,<sup>25</sup> as well as considerable development of new motion-picture projection equipment for television broadcasting purposes.

Experimental work on methods of recording the television signal on magnetic tape instead of film was announced during the year,<sup>35</sup> but despite repeated scheduling at engineering conventions nothing has been shown. Several companies are known to be working on this technique, but so far only Bing Crosby Enterprises has released publicity on the subject. The Crosby engineers use a 1-in. wide tape running at 100 in./sec. on which they record twelve tracks, one for sound and eleven for video. This results in the resolution of 260 times the information that a standard 15-in./sec. tape can record. According to many, this is far from enough for a good quality picture. Some forward-looking engineers project the curve of current advancement in this field, compare it with the advancement of the photochemical industry and foresee the end of the motion-picture laboratory in ten years. If sound and picture can be recorded on tape, say these men, so can left- and right-eye pictures. So can three primary color signals per eye; so can stereophonic sound. The high-definition, wide-channel, closed-circuit television camera may replace the motion-picture camera in the future.

For the first time in history, television broadcasting facilities were made available in Canada during the past year, a station being placed in operation in Toronto and one in Montreal.<sup>38</sup> This signified the inauguration of television throughout the Dominion.

1952 was a year of advances and expansion of television service in England. Early in the year, the B.B.C. extended

television service to cover the Lancashire and Yorkshire areas. In March, Scotland was reached and in August, South Wales. It is reported that 80% of the population of the British Isles can now enjoy satisfactory television reception in their homes. Experiments are under way for a relay to Belfast, so that Northern Ireland will be able to receive London programs. Considerable planning and preparation is in progress for the televising of the Coronation in 1953. An outstanding achievement was the transmission of programs from Paris to England in the summer of 1952. In addition to the long-distance relays involved, a change of standard had to be effected half way in the chain where the 819-line picture of the French Service was converted to the B.B.C.'s 405-line standard.

An interesting development in the foreign television field pertains to Australia. While there is no television broadcasting in Australia at present, it is anticipated that there will be at least one television station in each capital city within the next two years, operated by both Government and private enterprise. Standards for Australian television were laid down in 1950 and are still in force. Extracts from them are as follows:

1. The width of the standard television broadcast channel shall be 7.5 mc/sec.

2. The number of scanning lines per picture period shall be 625, interlaced 2 to 1, and the radiated signal shall be monochrome.

3. *Polarity of Modulation.* A decrease in the initial light intensity shall cause an increase in radiated power, that is negative transmission.

*Picture Frequency.* The picture frequency of the radiated signal shall be 25 per second and the field frequency shall be 50 per second, nonsynchronous with the power mains supply and held within a tolerance of  $\pm .002\%$ .

*Type of Modulation.* Within the television channel the visual radio carrier shall be amplitude modulated with both

picture and synchronizer signals. The type of modulation used in the aural transmitter shall be frequency modulation, the frequency deviation for 100% modulation shall be  $\pm 25$  kc. The polarization of the transmitted radio wave shall be horizontal.

### Theater Television

*Theater Television Projector Installations.* The number of theaters equipped with theater television projectors doubled during 1952. Approximately 50 installations were made, bringing the total number of theaters so equipped at the end of the year to 103.

*Theater Television Showings.* During 1952 there were five theater television shows which were distributed on a nationwide basis. Two of these were prizefights, these being the Marciano-Walcott and Maxim-Robinson contests. Theater television was used for the first time in 1952 for the distribution of a production of the Metropolitan Opera, the opera *Carmen*, which was shown in 31 theaters in 26 cities on December 11. Theater television was also used for the first time for a national sales meeting, the sponsor being Lees Carpets. The public service potentialities in theater television were shown in a program carried by the Federal Civil Defense Administration for the instruction of its workers in various cities.

*Eidophor.* 1952 marked the first semi-public showings of the new Eidophor theater television projection system.<sup>36</sup> During June of 1952 the Twentieth Century-Fox Film Corp. gave some twenty-five formal shows in its 300-seat theater at its home office building, 444 W. 56 St., New York. Some 3000 persons viewed these showings including the FCC, members of the Armed Forces, and other Government groups, as well as a complete cross section of management of the various segments of American industry. These shows were in full color using the field sequential (CBS) system. The technical standards employed were 25

frames/sec., 525 scanning lines with 2 to 1 interlace, a 12-mc video bandwidth, a 12 by 15-ft picture, and 5-ft-c highlight brightness.

*Theater Television FCC Proceedings.* The long-delayed theater television proceedings before the FCC commenced in October of 1952. In these proceedings the motion-picture industry is making its request for an allocation of channels in the microwave portion of the spectrum for the transmission of theater television programs from the point of origin to the various theaters. During the October session of the hearings, approximately two weeks were devoted to the presentation of the technical phases of the industry's case. This portion of the case was prepared jointly by the Motion Picture Association of America and the National Exhibitors Theatre Television Committee. The hearings were to be resumed in January of 1953.

Of particular interest are certain technical proposals which were made by industry representatives at the hearings and which are summarized below:

#### I. Video Signal Standards

*A. Video Bandwidth.* The proposed video bandwidth is 10 mc. This is based upon the requirement that theater television picture definition equal that of standard 35mm motion-picture film. In making this calculation, it was assumed that something in the order of 725 scanning lines might be required to reduce the visibility of the lines in a high-definition system to a tolerable value. It was also assumed that either the field sequential color system or some system similar to that being developed by the National Television Systems Committee employing mixed highs and color sub-carrier transmission might be used.

*B. Signal-to-Noise Ratio.* The required signal-to-weighted-noise ratio required for monochrome transmission is 46 db, and for field sequential color is 42 db. The weighting factor discriminates against the higher video frequencies, tak-

ing into account the reduction in response of the eye to fine detail and the reduction in response of the projection equipment to high-frequency components. The weighting factor was based upon a viewing ratio of 2.

*C. System Linearity.* It was proposed that the system be sufficiently linear so that the maximum deviation of the transfer characteristic from a straight line joining the ends of the characteristic at black-and-white levels should not exceed 10% of the total excursion from white level to black level.

## II. Channel Width

In order to transmit satisfactorily a video signal having the above specifications, it was proposed that a channel width of 30 mc be provided for carrier frequencies below 10,000 mc, and 55 mc for carrier frequencies above 10,000 mc.

## III. Number of Channels

Provision was requested for a total of six independent circuits. It was shown that each circuit would require two channels so that a total of twelve channels would be required for six circuits. This would require a total of 12 times 30 mc, or 360 mc. In addition, two pooled channels were requested for remote pickup use.

## IV. Position of Channels in Spectrum

Two alternative proposals were made for re-allocation of the microwave spectrum in order to provide an allocation of channels for theater television. These are summarized below:

### *Proposal No. 1*

a. Allocate the frequencies from 5925 to 6285 mc (now allocated for common carrier fixed services) for the exclusive use of theater television.

b. Provide a reasonable transition period within which the present occupants of the frequencies in a. above can move to some frequency between 6285 and 6425 mc which would be retained by the common carrier services.

c. If necessary, additional frequencies,

e.g., the 3500 to 3700-mc band could be allocated to the common carrier fixed services to compensate for this loss of the 5925 to 6985 mc band.

### *Proposal No. 2.*

If it is decided that the exclusive type of allocation for theater television contained in Proposal No. 1 is not feasible, it is suggested that provision for theater television be made in the rules on a frequency-sharing basis with the operational services. This could be accomplished as follows:

a. Classify theater television as an industrial radio service.

b. Expand the 6575 to 6875-mc operational fixed band downward to include the land mobile frequencies between 6425 and 6575 mc, thus providing sufficient bandwidth for theater television requirements.

## Television in the Armed Services

The Signal Corps Mobile Television System has provided a means of exploring the use of television as a tactical and training medium in the U.S. Army. The system provides, in mobile form, self-contained and self-powered equipment for lighting, for television, and for technically controlling the production of scenes from three field cameras. The combined audio and video can be fed simultaneously to kinerecording equipment and via microwave radio transmission to a remote receiver. Other mobile units provide for receiving and monitoring sound and video signals at the receiving point. Provision is also made to display the resulting television production to audiences on ten 16-in. monitor receivers and on a 6 by 8-ft projection receiver.<sup>37</sup>

Television equipment was successfully employed in launching a number of robot planes, or drones, against Communist targets in North Korea from the *U.S.S. Boxer*, a 27,000 ton Essex class aircraft carrier. While details of the Navy's system are secret, the drone bombing attack

is made in this way: The drone, armed with a powerful warhead, and equipped with television transmitting equipment and electronic control equipment, is catapulted from the carrier and guided to a predetermined altitude. Here an air-borne guide plane takes over control of the drone and directs it to the target area. At the time the drone is ready to make its pay-off dive, the guide plane is miles away, out of anti-aircraft range. Television signals from the drone enable it to be guided on to the target. All during its flight, from the deck of the carrier to the target, the progress of the drone is recorded in a specially equipped electronics room aboard the ship.

### **High-Speed Still and Motion-Picture Photography**

Since the last Progress Committee Report an exceptionally widespread effort has been made on a world-wide basis in the realm of photographic instrumentation. It is beyond the scope of these paragraphs to set forth this progress in detail. For more detailed analysis, the reader is referred to "Progress in Photographic Instrumentation in 1950,"<sup>38</sup> and subsequent annual reports to be published in this Society's *Journal*. The following analysis therefore is limited essentially to the Society's effort in the field of high-speed still and motion-picture photography and attendant ramifications.

Considerable work has been reported in the world's scientific literature on both sides of the Atlantic. The use of high-speed photographic techniques is expanding rapidly as a greater awareness of application is becoming more evident. The Royal Photographic Society of Great Britain during 1952 held a number of meetings the results of which were published in the *Photographic Journal*, Vol. 92B, Sept.-Oct. 1952. In addition, the Royal Photographic Society held a most interesting symposium at Cambridge University on October 4, 1952, with a number of papers specifically relating to

high-speed still and motion-picture photography.

Also in October of this year, the First International Symposium on High-Speed Photography was held by this Society in Washington, D.C. Forty-three papers were presented at these sessions which included participation by leading scientists from England, France, Germany, Canada and Sweden. This was a most successful meeting and the papers resulting will be published in these pages. The Society is to be congratulated for its part in fostering this program and for due recognition of the outstanding work of the Chairman of this Symposium, Mr. John H. Waddell. A number of papers on high-speed still and motion-picture photography were presented at the Chicago Convention of the Society in April 1952 and have subsequently been published.

#### *High-Speed Camera and Component Design.*

In order to provide for the study of phenomena which take place in very short time intervals, Dr. J. W. Beams<sup>39</sup> and his colleagues at the University of Virginia have developed, over a number of years, a high-constant-speed rotating mirror system. The mirror is magnetically suspended in a high vacuum and is imparted a rotation through the medium of a rotating magnetic field. The circuitry for operation of the mirror and for rotational speed measurement is given in the paper. Speeds of the order of 20,000 rps have been achieved with this system.

Design considerations for rotating prism-type high-speed motion-picture cameras were further discussed by Kudar,<sup>40</sup> reiterating, in the main, his previous thesis on this subject.

The Merlin-Gerin-Début Cameras made in Grenoble, France, were described by Gunzbourg.<sup>41</sup> These two cameras use essentially the same optical principle of multiple rotating objectives. The first, a 16mm 3000-frames/sec camera has 80 matched lenses and the other, a 100,000-frames/sec camera uses

three rows each of 250 matched lenses. These cameras provide for a relatively high resolution.

A high-speed rotating-mirror frame camera, utilizing C. B. Miller's isotransport system, which he first devised in connection with the NACA-Miller Model 2 Camera, forms the basis for a new instrument described by B. Brixner of the Los Alamos Scientific Laboratory.<sup>42</sup> This instrument provides for frame frequencies up to 3,500,000 frames/sec, utilizing 170 framing lenses working at  $f/26$ . An air turbine designed by Dr. W. E. Buck of the Los Alamos Scientific Laboratory with the assistance of Prof. J. W. Beams of the University of Virginia may be operated to 10,000 rps. The images produced are  $1.2 \times 1.4$  cm in size. A second model based on the isotransport system has been designed for 100,000 frames/sec operation providing for 90 images 20 mm in diameter. An electric motor drive provides a mirror speed of 550 rps.

*High-Speed Photography Applications.* High-speed cinematography utilizing commercially available apparatus has found a very wide range of application in the design, development and proof of automotive vehicles, at the General Motors Proving Ground. Painter<sup>43</sup> describes techniques for light measurement, installation of apparatus and analysis of records.

Internal combustion engine research using high-speed motion-picture instrumentation was described by Bowditch,<sup>44</sup> involving both specially designed and commercial high-speed cameras. Frame frequencies to 5000 per second were employed. One supposes that additional work is going forward at higher frame frequencies in order to study more fully these rapid phenomena of combustion, although none is described in this paper.

Photographic instrumentation, essentially multistation stills using high-speed flash techniques, was developed for use at the U.S. Naval Ordnance Test Station Aeroballistics Laboratory. Barkofsky<sup>45</sup>

describes the physical design of this free flight range for missile testing which includes, at a number of stations, means for producing vertical and horizontal images of projectiles in flight. Techniques and circuitry have been developed for providing multiple images at each station.

An airborne camera which takes  $\frac{1}{4}$  by  $2\frac{1}{4}$ -in. pictures at rates up to 450 frames/sec on 70mm film has also been developed by the U.S. Naval Ordnance Test Station. The film is stationary during exposure. The long, thin aperture shape, high frame rate, and small size and weight make it a useful tool for work in ordnance, aircraft, and machine design.

The Springfield Armory has made further developments with rapid methods for quantitative analysis of high-speed motion-picture data. A special slide rule provides for the mechanical computation of time, displacement, velocity, and acceleration of a moving machine part in mechanics research.

High-speed motion-picture photography and continuous-film cathode-ray-tube oscillography were used in concert in the study of cardiac function. Diastolic and systolic blood pressures together with motion-picture and high-speed motion-picture photography of animal hearts have provided a new insight into blood flow and heart action as reported by Fields, Fields, Gerlach and Prinzmetal.<sup>46</sup>

*Miscellaneous.* A. C. Keller of the Bell Telephone Labs. discussed the advantages inherent in high-speed motion-picture photography from an economic viewpoint.<sup>47</sup> Gilkeson and Turula,<sup>48</sup> in a paper before this Society, set forth several series of lenses which may be adapted to high-speed motion-picture cameras. Included are several catadioptric telephoto lenses; focal lengths from 3.7 mm to 80 in. are covered.

*Continuously Moving Film Systems.* Impact loading deformation was studied by means of a rotating-drum camera de-

signed at the Armour Research Foundation.<sup>49</sup>

A novel apparatus was designed by Buck<sup>50</sup> using an interferometric means for the recording of high-speed transient pressure changes.

**Light sources.** The excitation of certain gases such as argon by an explosive shock front results in a relatively short-duration high-intensity flash. Winning and Edgerton<sup>51</sup> have studied this phenomenon and have continued the work of others in the development of explosive argon flash lamps. The exposure duration may be controlled by the thickness of the argon layer.

**X-Ray Motion-Picture Photography.** X-ray motion-picture photography, since the early 1900's, has proven to be of considerable value in medical research and diagnosis. Weinberg, Watson and Ramsey<sup>52</sup> at the Medical School of the University of Rochester recently developed a new 70mm motion-picture camera for the indirect x-ray recording method (the image of the fluorescent screen being recorded). A special  $f/0.75$  lens was developed by the Eastman Kodak Co. for use in this system.

**Data Reduction.** Griffin and Green,<sup>53</sup> of the U.S. Naval Test Station, Inyokern, have studied considerations of camera design and photographic image affecting the assessment accuracy of records taken for measurement. For certain camera systems, errors in film measurements were reported to range from 2 to 75  $\mu$ . An analysis was made of the means necessary to minimize such reading errors.

**Summary.** The above represents a small but very significant portion of the world's photographic literature on the subject of high-speed motion-picture and still photography. This Society, it is believed, has made great strides in its function of dissemination of basic information in this field. The effort of the High-Speed Photography Committee in the future is expected to be directed to furthering this end to an even greater extent and the Committee is counting heavily

on the Society's membership for increased participation.

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# Color and Reflectance of Human Flesh

By ALLEN STIMSON and EDWARD FEE

A recent investigation of the variation in spectral reflectance and chromaticity of the flesh tones of various individuals is described. Spectrophotometric reflectance measurements were made on the face, arms and hands of several individuals having different complexions and degrees of sun tan. Spectroradiometric measurements were made of many phases of daylight. The variations in chromaticity of flesh tones due to daylight variations were calculated. The reflectance of the flesh was computed in terms of the response of an exposure meter to determine the exposure constant for reflected-light readings taken on the human face.

THE MOST important and most frequently photographed subject is the human face. Observers are very critical of the photographs with regard to delineation, contour, color, lighting and expression. This paper reports a brief investigation of the color and reflectance of human flesh as they influence appearance and exposure.

The appearance of the color of the human complexion obviously varies between individuals. This is due to differences both in chromaticities and in luminances. The differences in chromaticities of three girls representing

fair, normal and sun-tanned complexions when observed by illuminant C are shown in Fig. 1. With these particular individuals the differences in chromaticities are not great. The principal differences in color are in luminance, but this coordinate is not represented on the chromaticity diagram. The luminance differences are apparent from the spectral-reflectance curves of Fig. 2. These were made by having each subject place her cheek against the measuring aperture of the G-E Recording Spectrophotometer. The sun-tanned complexion is the lowest curve C.

In the illustrations the same letter designations refer to the same person.

The appearance of a person's face also varies widely in color depending upon the illuminant. In Fig. 3 is shown the variation in chromaticity of a girl's cheek when evaluated by the standard observer. Each point on this diagram

Presented on October 9, 1952, at the Society's Convention at Washington, D. C., by Allen Stimson, and Edward Fee, Meter and Instrument Dept., General Electric Co., 40 Federal St., West Lynn 3, Mass. (This paper was received on Nov. 26, 1952.)

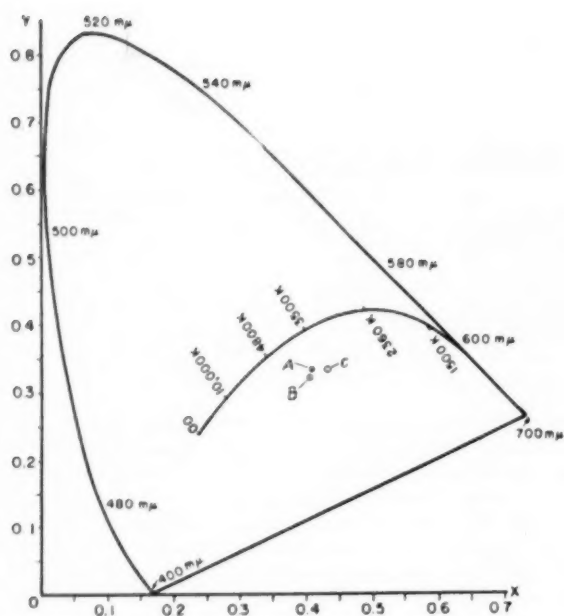


Fig. 1. The chromaticity of the cheeks of three girls having different complexions as viewed with illuminant C. The locus for blackbody radiation is also shown.

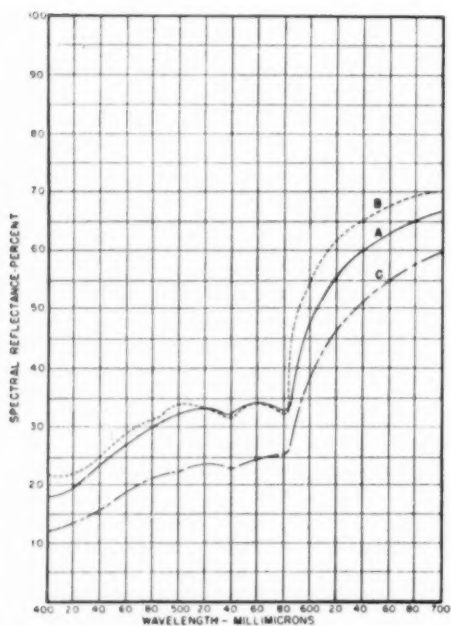
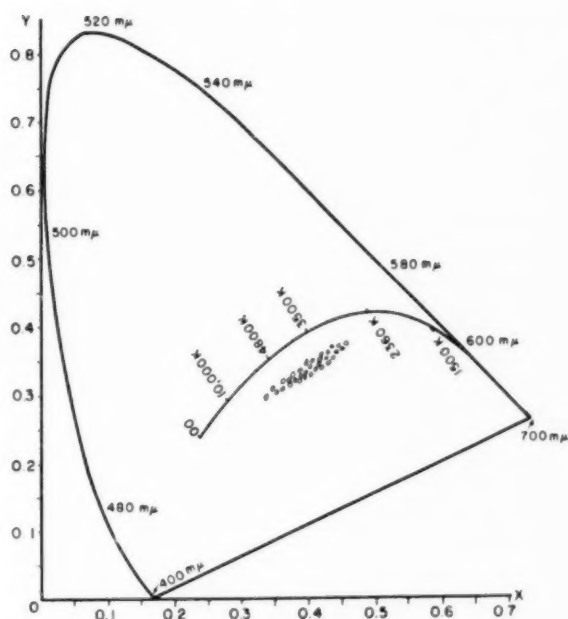


Fig. 2. Spectral reflectance of the cheeks of the three girls represented in Fig. 1.

Fig. 3. The chromaticity of girl B's cheek varies widely when observed under different measured-daylight spectral distributions. The locus for blackbody radiation is also shown.



represents the chromaticity under different measured-daylight, spectral-energy distributions. Each of these distributions was measured with a G-E Recording Spectroradiometer during the summer of 1951 in the vicinity of Boston.

The change in chromaticity represented in Fig. 3 is not so readily apparent because the change in illumination produces corresponding changes in the color of white or familiar objects which may be observed at the same time. The white surface is still perceived as white in the changing illumination because of previous experience or association; and by comparison, the variation in the observed color of the human skin does not vary nearly so much as the change in chromaticity suggests. However, the change in the illuminant will change the color reproduction on photographic color film, and can be taken into consideration when fidelity is desired.

It will be noted that the variation in color is quite considerable. Which

color is most pleasing and which is least pleasing is difficult to evaluate. However, our own experience suggests that the purple and bluish colors are considered less desirable than the pink-orange colors. It has further been reported that the yellowish appearance of flesh is also objectionable.

To study the variation in color of human flesh as determined by exposure to the sun, the spectral reflectance of the flesh was measured on the outside of the forearm and the inside of the forearm of two different individuals as shown in Fig. 4. In this illustration, the darker-skinned individual is designated by H and the lighter, by F. Curves H2 and F2 designate the outside of the forearm where there is sun tan, and H1 and F1, the inside of the forearm where there is little sun tan. It is noted that there is little difference between these two persons' flesh colors where there is sun tan.

As a further check on the effect of sun tan, a spectral reflectance curve of the

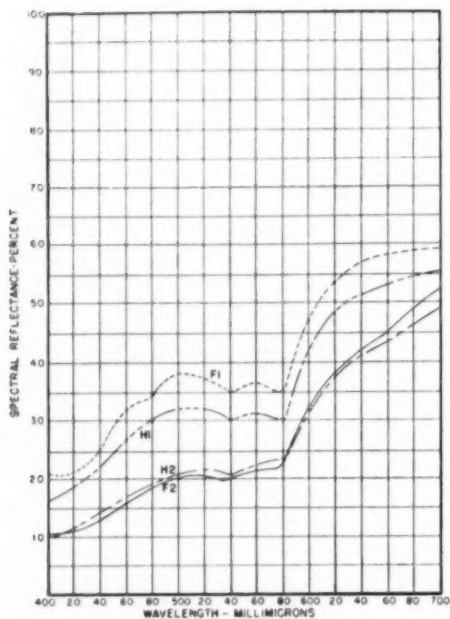


Fig. 4. Spectral reflectance of the inside (1) and outside (2) of the forearm of two men, H and F showing the effect of sun tan.

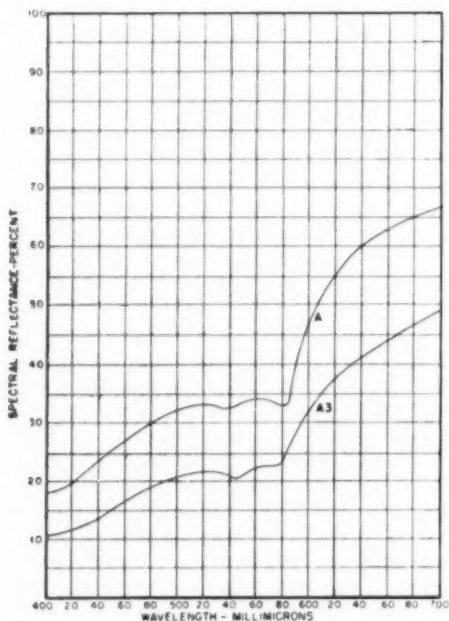


Fig. 5. Spectral reflectance of the same girl's cheek A, and sun-tanned shoulder A3.

Fig. 6. Spectral reflectance of the palms of the hands of six different people.

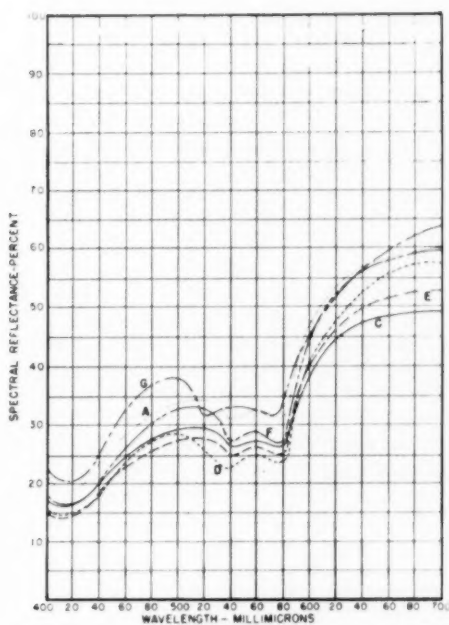
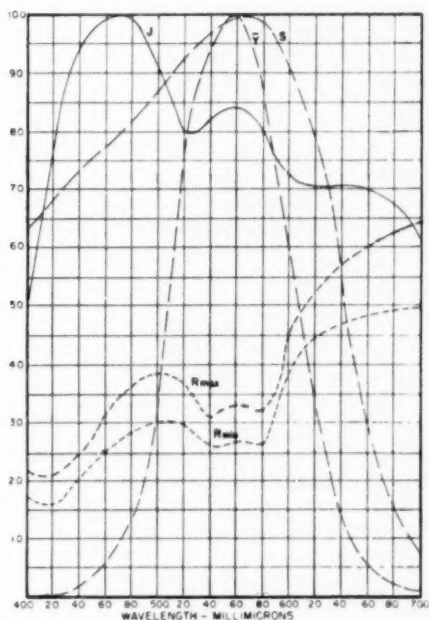


Fig. 7. Spectral reflectance of lightest,  $R_{\max}$ , and darkest,  $R_{\min}$ , palm measured, the luminosity function  $\bar{y}$ , and the spectral sensitivity of the exposure meter cell S, and the energy distribution  $J$  of illuminant C.



sun-tanned shoulder of the girl indicated by letter A in Fig. 2 is shown in Fig. 5 as curve A3.

In measuring photographic exposure with a reflected-light exposure meter, it has been the practice of many people to make a close-up reading on the face of the subject or on the palm of the photographer's own hand and double the indicated exposure. Previous investigation indicated that the total diffused reflectance of the human hand as measured with a photoelectric exposure meter would be about 38%. To check this figure, the spectral-reflectance curves for the hands of six different people were measured as shown in Fig. 6.

The reflectance was evaluated in terms of both visual response and selenium-cell response. The latter is the important value in designing an exposure meter.

The spectral reflectances of the lightest and darkest hands are shown in Fig. 7. The luminosity function  $y$ , spectral sensitivity of the exposure-meter cell,  $S$ , and the energy distribution,  $J$ , of illuminant C are also illustrated.

The total diffused reflectance based on the visual response of the standard observer was calculated from the formula:

$$R = \frac{\int_0^\infty J_\lambda R_\lambda y d\lambda}{\int_0^\infty J_\lambda y d\lambda} \quad (1)$$

Using the values shown in Fig. 6, the following values of visual reflectance were found:

$$\begin{aligned} R_{\max} &= 36.8\% \\ R_{\min} &= 34.0\% \\ R_{\text{av}} &= 35.4\% \end{aligned}$$

When both incident and reflected light are measured with a meter, the energy and responses in the near ultraviolet from 360 m $\mu$  are considered. By means of equation (2) the reflectances  $R_m$  measured with an exposure meter were found:

$$R_m = \frac{\int_0^\infty J_\lambda R_\lambda S_\lambda d\lambda}{\int_0^\infty J_\lambda S_\lambda d\lambda} \quad (2)$$

$$\begin{aligned} R_{m \max} &= 36.2\% \\ R_{m \min} &= 29.4\% \\ R_{m \text{ av}} &= 32.8\% \end{aligned}$$

The average value of  $R_m$  is 7.3% less than  $R$ , and 13.7% less than the original value of 38%. These differences would be much less with illuminant A, and slightly greater with an equal-energy illuminant.

Reflected-light exposure meters have in the past been calibrated for an average scene reflectance of between 15 and 20%. It was assumed that human flesh had twice the reflectance of the average scene, or 30% to 40%. The new value, 32.8%, and the old value, 38%, both fit within this range. It would, therefore, appear that the practice of reading the brightness of the face and doubling the indicated exposure is a very good method of using the meter. This procedure tends to equalize the brightness of faces so that dark complexions do not appear too dark and light complexions do not appear washed out in color pictures.

Other investigations of the color of human flesh have been made and reference has been suggested to the work of E. A. Edwards and S. Q. Duntley on "Pigment and Color in Living Human Skin," in the *American Journal of Anatomy*, 65: 1-33, July 1939 and on "Analysis of Skin Pigment Changes After Exposure to Sunlight," in *Science*, 90: 235-237, Sept. 8, 1939.

In conclusion we may say that the color of human flesh varies between individuals but varies even more with the color of the illuminant. The flesh tones vary in lightness and darkness, but this difference is automatically taken into consideration when the exposure reading is made by reflected light from the face of the subject.

# Televising a Symphony Orchestra

By RUDY BRETZ

**The televising of a symphony orchestra is a very complicated project. It requires the thought, the preplanning and the thorough rehearsal associated with the most elaborate live network productions. Yet such projects must often be attempted on a local scale by small commercial or educational stations with extremely limited facilities and rehearsal time. The following article describes a production method which was developed to meet such a situation.**

WHEN THE University of Minnesota undertook to produce a series of ten one-hour telecasts of the Minneapolis Symphony Orchestra, the author was invited to produce and direct the first four programs. Many of the problems which were faced in these productions were new, and the solutions which were found for them are recorded for the benefit of others who may attempt similar productions.

These programs were to be up to network standards of program quality, while produced under the limitations of local small-station operation. Instead of some ten hours of camera and facilities rehearsal, as one would expect in producing a network show in New York, we were able to get both cameras and orchestra together for a total of only an hour and a half. To the reader who knows television studio methods this will seem an incredibly short time in which to rehearse an hour's show which is completely scripted (there is no more

exact script than a musical score) and which must be cut with absolute accuracy, on the exact bar, and often on the exact beat of the right bar. When the trumpets play a solo passage, for example, you must show the trumpets alone, but when they finish playing you must cut away from them immediately or they will be seen laying down their instruments, blowing the water out of their horns, etc., while some other unseen section of the orchestra has taken over.

The problem of visualizing the music without resorting to the obvious method of showing the players at work brought forth some rather interesting experiments. There is grave doubt in some people's minds that music *can* be visualized. Most music is entirely nonvisual and has existence only in the ear, yet if symphony orchestras are going to be broadcast, and television is the predominant broadcasting medium, certainly we must find ways of telecasting music. Pictures of the orchestra seemed to be the most acceptable to most viewers. We made some experiments with the creation of semiabstract images, shadows and figures on a rear-projection screen.

A contribution submitted on February 25, 1953, by Rudy Bretz, Television Consultant, Park Trail, Croton-on-Hudson, N. Y.

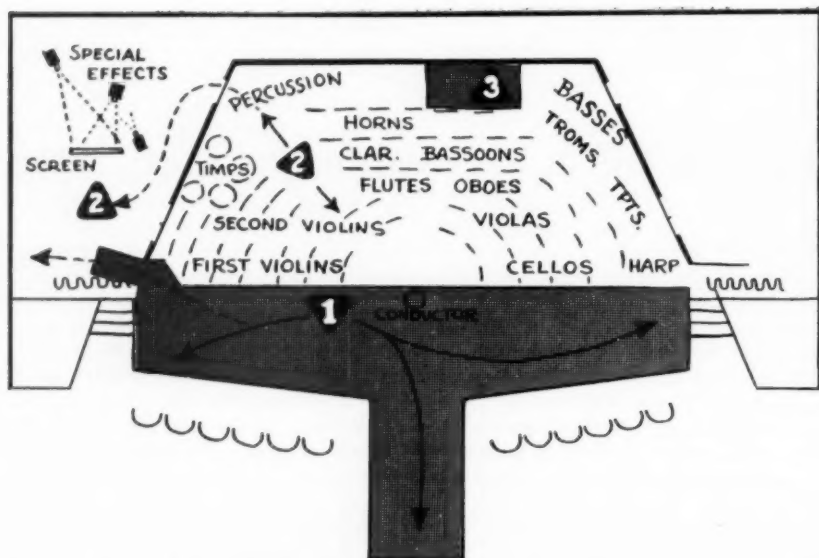


Fig. 1. Diagram of orchestra setup. Dark areas are special platforms constructed for the production, 18 in. above stage level. Ramp at left allowed camera 1 to move back-stage for intermission features.



Fig. 2. Stage of Northrup Auditorium during rehearsal. Front platform was built 18 in. above stage level to give camera some elevation and allow for camera movement. If a fourth camera had been available it would have been used on platform along with camera 1. (Platform had to be struck and reassembled each week.)

This technique met with reactions varying from exceedingly favorable to highly critical. Both musicians and non-musicians were among the supporters and also among the critics.

Presumably the usual arrangement of an orchestra on a stage is primarily for the sound and appearance before an audience. However, there was to be no audience at these concerts and it was the writer's hope that the orchestra could be arranged to suit the cameras. The conductor would not allow this, however, since it would throw off his musical balance. If the players could not be moved, then the cameras would have to be carefully placed where they could get good individual close-ups, if necessary, of musicians in all parts of the orchestra.

It would have been possible, of course, to photograph even the most distant players with long lenses from the front of the stage, but long-lens shots are often flat and uninteresting, whereas closer shots using wider lenses usually have a more dynamic quality. After considerable experimentation during regular orchestra rehearsals the week prior to the first show, one camera was placed within the orchestra and another at the back, leaving the third to operate from the front of the stage.

Another unchangeable condition with which we had to be satisfied was lighting. By taking the colored roundels off the stage borders so all stage lights were white, a level sufficient to use a lens stop of  $f/6.3$  was obtained. No accurate meter was at hand, but it was assumed that the light ranged from 10 to 20 ft-c. A higher level would have allowed the use of smaller stops and hence better depth. Any attempt to add spots, even from quite a high angle, brought violent objections from the musicians, to say nothing of the conductor. Relamping the stage borders with photoflood lights was not possible without rebuilding the stage wiring so it could carry the additional load. The lighting was flat, and

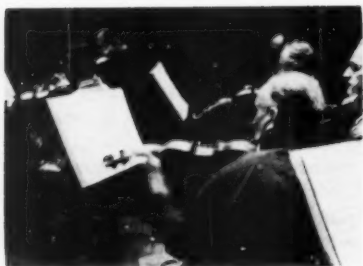
could have been improved had directional units of various types been utilized for modelling light. However, a very large area of stage and 92 musicians were involved, and a great number of units would have been necessary. Moreover, cameras were shooting from all sides and what would have been pleasant modelling light from one angle might easily have been excessively hot front light from another.

All told, we considered ourselves lucky to have a legitimate excuse to do nothing about the lighting. Perhaps this was best anyway, since the result was at least realistic, looking just as an orchestra actually does look at a concert. Beautiful side and edge lighting would have given an unreal studio effect. The depth of field was, incidentally, quite adequate at  $f/6.3$ , in spite of the cameras being rather close to some musicians and far from others in the same shot.

The diagram in Fig. 1 shows the arrangement of the orchestra which the conductor, Antal Dorati preferred, and the space which we managed to clear at the back and within the orchestra for camera placement and movement. It was found that a camera could not be placed between the conductor and any player in the orchestra without interfering with the conducting of the music, *but* if an aisle were made running directly toward the conductor, the camera would be in no one's way.

Figure 3 shows several of the close shots made possible by placing camera 2 in this aisle. An additional advantage was obtained in placing this camera on a pedestal so it could shoot from a low angle (for a line of violins one behind the other) or from a high angle (when it was necessary to shoot over a foreground musician who was not playing and cover a player several stands away). Excellent dolly and truck shots were also made on this camera.

Camera 3, on an 18-in. platform at the back, could take excellent close shots of otherwise inaccessible sections of the or-



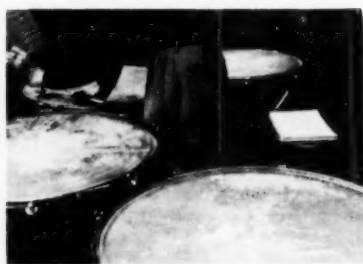
Camera 2, 50-mm lens



Camera 2, 90-mm lens



Camera 2, 50-mm lens



Camera 2, 50-mm lens



Camera 2, 90-mm lens



Camera 3, 50-mm lens



Camera 3, 90-mm lens



Camera 3, 90-mm lens

◆ **Fig. 3.** A series of shots taken with Leica camera during regular orchestra rehearsal to aid in planning the show. Close shots on horns, basses and other instruments far up-stage show advantage of placing cameras 2 and 3 within the orchestra.

chestra (Fig. 3). Both cameras 2 and 3 could take shots of the conductor with a variety of lenses.

The four standard studio lenses (50-mm, 90-mm, 135-mm and 8½-mm) were used on each camera except camera 2, which had all but the 8½-mm and would have been equipped with it had one been available.

It was inevitable that the two cameras within the orchestra would show in occasional wide shots from the front. This was welcomed as a plus rather than a minus factor, as long as the movement of a background camera or cameraman did not distract attention from the orchestra. That danger existed only in close shots where the camera would be relatively large, and in all such shots, the cameras could be avoided. We were careful to identify the cameras at the opening of each show, having the Master of Ceremonies say something like "Our cameras are in place among the musicians to show you the orchestra from the inside, etc.," thus frankly admitting to the audience that the cameras were there. It was hoped that they would then be accepted just as the convention of a microphone in the M.C.'s hand is accepted. No one said that the equipment was distracting, and some felt that they enjoyed seeing the cameras occasionally since it kept them aware that the program was a live telecast. This was the plus value that we had hoped for — an increased sense of immediacy.

Each program included: about 45 min of music; 6 min of opening, close and transitions between numbers; and about 9 min of a special intermission feature. The purpose of the intermis-

sion was to point up the relation of the orchestra to the region that it serves. The preplanning and rehearsal on the music were, of course, the major problem.

The coverage of the orchestra, accurate to the exact beat, would not have been possible without a full-time musical director. The writer was extremely fortunate to have Burton Paulu, a symphony musician himself and supervisor of the entire project, working in this capacity. Paulu studied orchestral scores for the selections to be telecast, listened to recordings of the numbers, and drew up suggestions for camera shots. Then Paulu and the writer got together for almost two solid days to block out the shots. This meant playing the recordings over and over again, while visualizing the camera shots. It was also necessary to visualize the action of each camera while it was *off* the air, to determine if there was enough time allowed to change position for the next shot.

While the orchestra was engaged in one of its regular rehearsals, the writer had taken a Leica camera with 50-, 90-, and 135-mm lenses into the orchestra and made shots from each camera position, as a memo to help in the planning. Some of these pictures are shown in Fig. 3. These were extremely valuable during camera blocking.

Each shot was numbered and the score was marked in red with these shot numbers, which ran consecutively throughout each piece of music. Within each shot the individual bars were consecutively numbered in black on the score (Fig. 4). With the playing of the music, the musical director would follow the score, reading off the number of each bar and in a slightly louder voice, the number of each new shot.

The director's script was then quite simple. It was divided into five columns (Fig. 5) as follows. The first column contained the shot numbers; the second column, the camera that was to be used.

The image shows a page of a musical score, likely for a film, with staves for various instruments and vocals. The score is marked with vertical lines representing shots and numbers indicating the number of bars in each shot. Handwritten notes above the staves indicate camera movements and picture changes.

Handwritten notes above the staves include:

- 13 (cam 3 bridge)
- 14 (cam 2 picture 3 - Tel. horse)
- 15

The staves are labeled on the left side:

- Clar (B)
- Fag
- Hörn (in F)
- Viol. I
- Viol. II
- Br
- Vol.
- CB
- kl. Fl.
- gr. Fl.
- Ob.
- engl. Horn
- Clar (D)
- Clar (B)
- Basscl (B)
- Fag
- Temp (in F)
- or. Rhyth.
- Becken
- Viol. I
- Viol. II
- Br
- Vol.
- CB

The score is marked with vertical lines representing shots and numbers indicating the number of bars in each shot. The numbers are: 2, 3, 4, 5, 6, 7, 8, 9, 1, 2, 3, 1, 2, 3, 4, 5.

Fig. 4. Score marked in shots and bars.

The third column indicated the lens which would probably be found best for the shot. The fourth column, the widest, listed the subject of the shot and any camera movement which was to be

made. The final column, the most important, listed the number of bars included in the shot. Since many of the shots came at 2- or 4-bar intervals, there would be no time during the running

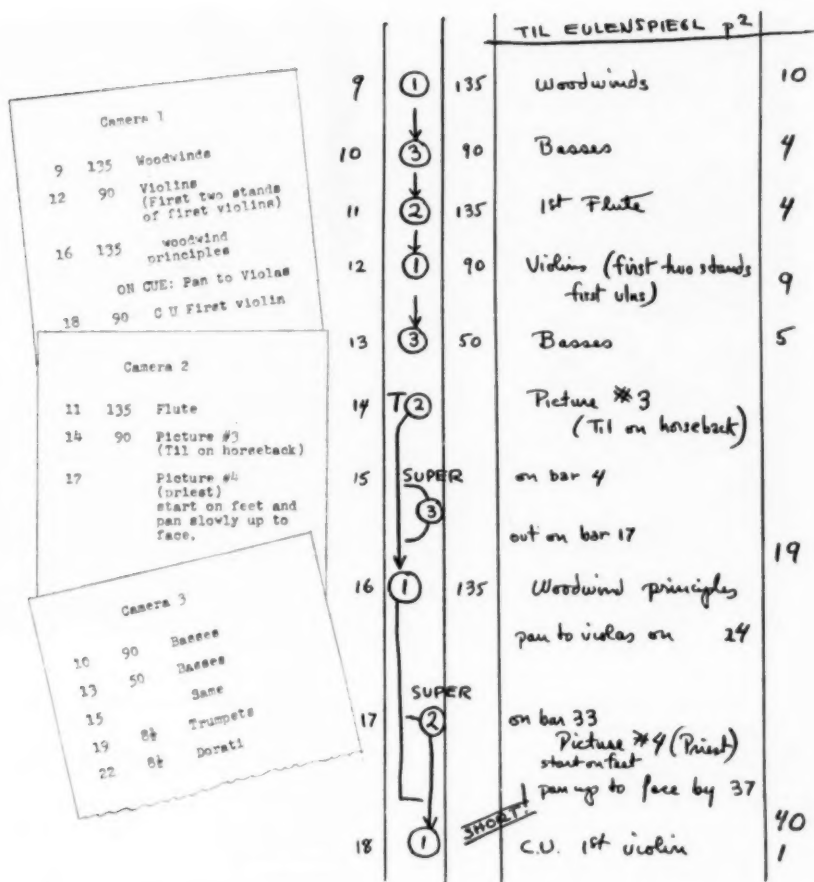


Fig. 5. Directors' script (right) lists consecutive shot number, camera number, lens, subject and camera movement and number of measures duration. Arrow to camera number signifies dissolve, T signifies a take. Individual camera cue sheets are shown at left.

of the show to give instructions to cameramen. Thus the camera cue-sheet method was used.

An abstract of the director's script listing only one camera's shots (see example in Fig. 5) was prepared for each camera. During the rehearsal and air show the writer would announce into the intercommunication system the number of each shot so that the cameramen

would not lose their places. Some kind of camera cue-sheet is used in many television studios for scripted shows.

Although the shots were thoroughly planned by this stage, the show was far from ready to go on the air. Remote-unit cameramen from the local station (WCCO-TV) would have to do the program after an hour and a half rehearsal on the day of the show. There



**Fig. 6. Camera 1 with cameraman, student assistant and student cable boy. RCA tripod dolly proved exceedingly flexible, capable of smooth movement in any direction at any time.**

would be no time then to stop and go over difficult shots if the cameramen didn't understand clearly what was wanted the first time. There would be no time to make changes if shots didn't work or there was insufficient time to change position between shots. To meet this need, an entire extra day of rehearsal with facilities was arranged without the use of the WCCO-TV equipment or cameramen at all.

The University of Minnesota had acquired some months previously a dual image orthicon chain, secondhand and in bad condition, but capable of making pictures. Although television courses have not begun at the University, enough advanced radio students could be found to man the equipment and form an adequate floor crew. The stage of the auditorium was set up in exactly the same manner as it is set for the orchestra, except that instead of players in the chairs, we put large placards identi-

fying the respective instruments. The stage was literally a sea of placards reading "1st bassoon," "second oboe," "first cello," etc. The two cameras were placed in the positions of one and two, and we proceeded to take the shots as called, although all that showed on the monitors were the names of the instruments. Camera 3, having the simplest shots to make, was represented by a student on earphones equipped with a viewing box. It was his responsibility to speak up if he could not get a shot or found unwanted floor crewmen in the background of a close shot on the conductor. Time and labor being very cheap, it was possible to do this rehearsal in a very leisurely fashion, compared with most television rehearsing. Two hours were spent on blocking the action for opening, closing, transitions and the intermission segment, and then after a lunch break, three or four hours were spent rehearsing the music. The re-



**Fig. 7. Camera 2 and camera 3 within the orchestra. Clock disappeared from wall and orchestra members donned afternoon formal jackets after rehearsal.**

cordings were played over a loudspeaker so that all could hear, and whenever trouble was found, the records could be stopped and reset and the troublesome section run again.

On the first show, errors in planning were uncovered during this rehearsal. On the latter shows the planning had improved and few shots were unworkable; but the student cameramen also had improved, and more complex effects could be worked out, often at a student cameraman's suggestion. Not the least important part of this rehearsal period was the training and rehearsal it gave to the director and his musical assistant. Even with a script as carefully worked out as the one described, television directing is still largely a matter of memory. This script, like any other, served mostly to remind rather than guide the director, and the more often he had gone over the

music, the better he would know it at the time of the final show.

Each cameraman was made responsible for his own cue-sheet. If any changes were made in it during the day, he would take it home and retype it, for it would be his responsibility to see that the same shots were made the following day. Here is the most significant part of this rehearsal method. Nothing that was learned was wasted, even though the actual cameramen who were to do the show were not present. When the professional cameramen went to work, each had an assistant, working beside him, also on earphones to the director, acting as a production assistant, to keep track of the cue-sheet and help him get the right shot at the right place and time (see Figs. 6 and 7).

On the day of the show the mobile unit left the WCCO-TV studios about

8:00 o'clock in the morning. Three cameramen, an audio engineer and a technical director were assembled at the scene of the production by 9:00 o'clock and began the running of cables and setting of the microwave transmitter on the roof of the auditorium. A single Altec pencil microphone was suspended over the conductor's head. By 10:30 the cameras were warmed up and ready to make pictures. An hour was then spent in rehearsing the 15 min of open, close and intermission action which had been worked out the previous day. At 11:30 the crew went to lunch.

The orchestra was available to us for a total of three hours, no more, no less. This included the hour of the show and the necessary half-hour break just before show time, leaving an hour and a half of actual rehearsal time with both orchestra and cameras together. This allowed for no more than one straight run-through without stopping. The additional half-hour was split into two 15-min periods, one ahead of the run-through and the other after it, during which the conductor was told he could rehearse anything he wanted. We used the first 15 min to work out shots which involved difficult camera movement, and the latter 15 min plus part of the half-hour break before air time we devoted to a discussion session between director and cameramen, in which we ironed out any misunderstandings and reviewed any changes we had found necessary during the dress.

Since the directing had to be done from a typical mobile unit truck (Fig.8) there was room for only three people in front of the monitors: the musical assistant, the director and the technical director (who did the video engineering). Thus, mostly as a practical expedient, it was decided that the director would work his own switching system. This is not an unusual method of operation, especially at small stations on simple and unrehearsed shows. In the case of this production, in spite of its complex-

ity, this method worked out extremely well. Cuts could be more accurate; the director could feel the music and switch accurately with the beat. Especially when slow dissolves or superimposition effects were desired, having the switching system under one's own control is a marvelous advantage. To a certain extent, it was like painting your own picture after years of having to tell somebody else how you wanted the brush handled.

Since it was not necessary to call shots in the usual fashion, such as "take two, take one, etc.," the director called instead the number of the shot (fifteen, sixteen, etc.) at the moment of each take or dissolve. Figures 6 and 7 show the cameramen and their production assistants with the cue-sheets attached to the cameras where they could be easily followed.

Since the director was relieved of the need of calling set-up instructions to the cameramen, this system was like that used in some studios where the assistant director gives all instructions to the cameramen that are setting up shots. In this case, however, the director actually had three assistant directors, each responsible for setting up the shots of only one camera. It was only necessary to check each shot before taking it to make sure it was on the right subject and properly framed. A few errors were always caught in each show at this last possible moment.

Another responsibility of the television director on the usual show is the timing of the program. The assistant director beside him follows the stop watch and lets him know whether the show is running long or short. It is then up to the director to make a decision as to what is to be cut or added. In this production that would be clearly impossible. Neither director nor musical assistant could take his attention away from script or score to compare timings with a stop watch, much less to make arrangements for cutting or stretching. For this



**Fig. 8. Control desk in mobile unit truck. Left to right: Burton Paulu, musical director; Rudy Bretz, producer-director; Lionel Wittenberg, technical director. Audio was operated from driver's seat of truck.**

reason the entire responsibility for timing the show was placed with Irving Fink, (assistant producer) who functioned as floor director during the show. This worked out very well. Cutting and stretching could not be accomplished with the music, of course; so these changes had to be made in the intermission and other transition periods. It was only necessary for the floor director to advise the director of what he was planning to do.

It would have improved the show if the audio pickup could have followed more closely with the shots. A few extra microphones to augment certain sections would have improved the sound. For example, when only the first flute plays, we must show only this one musician. The camera seems to be only 3 ft from him. It does not sound right to hear a flute some 30 ft from the microphone. The close-up shot calls for close-up sound. The usual orchestra conductor would be very unlikely to allow this,

however, unless he were working much more closely with the television producer than was the case with us.

So far we have been discussing the methods of handling the shots of the musicians. One number in each show was handled in a different manner, however. The script shown in Fig. 5 indicates one of these experiments. Antal Dorati, the conductor, is an amateur artist and we prevailed upon him to make a number of sketches depicting the episodes in *Til Eulenspiegel's* merry life which Richard Strauss had described in the number we were doing. During the playing of the number these were interwoven with the shots of the orchestra.

Throughout the production we had a department of special effects at work, experimenting with various methods of creating abstract images on a screen, and adapting these to certain of the musical numbers. Several techniques were used, including shadowgrams and mul-

tiple shadows, projections and distorted images, and reflected images. Some of the devices were similar to those used by Thomas Wilfred in his Clavilux and Lumia instruments. Some were combinations of many effects which had been used separately before. All of this was created on a rear-projection screen (we used a piece of tracing cloth for lack of better material). Camera 2 was dollied backstage where it could frame up on the screen (Fig. 9). The staff of special effects people had been practicing for days with the records so their effects would fit perfectly with the music.

This group consisted of two experimentally minded art students and two dancers, also with an experimental turn of mind. A creative engineer was in charge of the group. The most valuable technique involved reflecting an image from a flexible mirror. A shape was cut out of a sheet of black paper and laid against the mirror. Bending the mirror then twisted, distorted and so turned the image on itself that it seemed to be moving in three dimensions. Dancers seemed best able to handle this new skill.

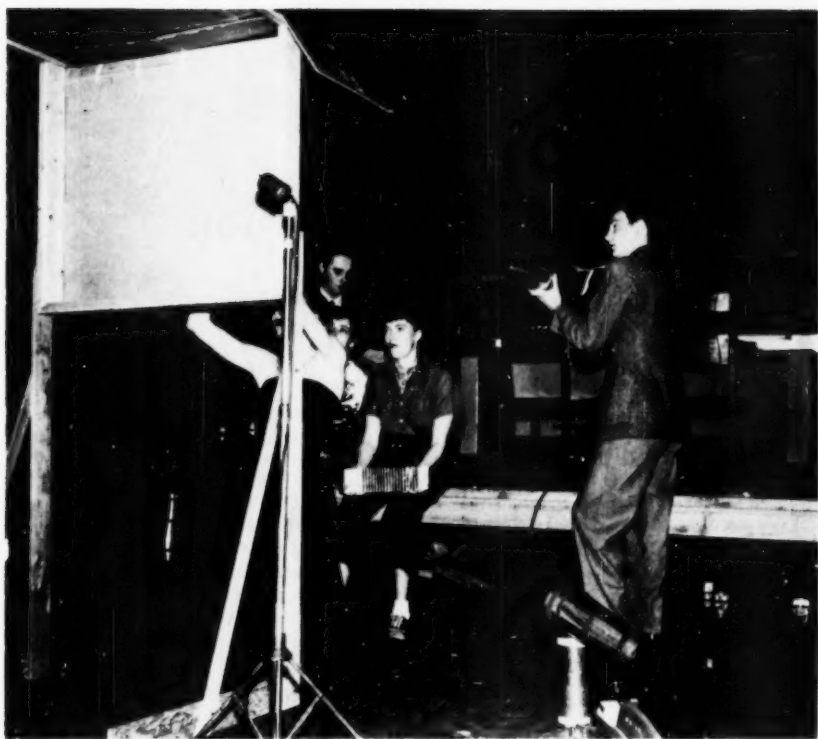
The first time the effects were used, on the three-cornered hat dances, we attempted to sustain a full 10 min with effects alone, the images being entirely abstract. Another time we did the *Wiener Blut waltz*. This called for semi-realistic symbols of Vienna, and of the waltz. A dancer was shadowed on the screen by a soft distorted projection and onto this shadow area a group of small dancing figures was reflected. They danced individually, gliding and turning and passing each other. Shots of the orchestra were then integrated with the effects: the dancer stepped back from the screen, toward the projector, so she covered a greater area with her shadow, and into this area the violin section, an overall pattern of violins and bows, was superimposed. This technique shows great possibilities, not just for classical

music, but for popular music as well, and deserves to be further developed.

A rough index of the elaborateness and the real cost of a production can be arrived at by totalling up the number of man-hours that went into it and dividing by the minutes of air time. Some network shows require 50 to 100 man-hours per minute. The Army Signal Corps once estimated that it takes 400 man-hours to turn out one minute of training film. Most small-station television productions and most educational television programs run about 2 to 3 man-hours per minute. The man-hour expenditure for an average show in this series ran about as follows:

	Man- hr
Production personnel (Dir., Asst., Musical Dir.)	120
Student cameramen	40
Art Work	5
Special Effects	160
(This figure is extremely high because the work was experimental, performers had to be trained from scratch, etc.)	
Narrator (WCCO announcer)	8
WCCO camera crew and engineers	48
Stage hands	64
Carpenters (for assembling of platform each week)	57
Musicians (92 players and conductor)	279
Total	781
or 13 man-hr/min	

This is a far cry from the simplicity of a radio pickup of a symphony orchestra, yet far removed also from the complexity of making a film of the subject. It is expected that many educational stations will want to telecast local orchestras. It seems clear to the writer, certainly, that this cannot be done in a very much simpler way. Experimental effects need not be attempted, of course, and simpler productions could be planned for the intermission segments. Under different circumstances, production time, including musicians, could



**Fig. 9. Special effects crew at work. Microphone was used to pick up sound of instruments which were played in silhouette against rear-projection screen.**

be trimmed to perhaps 7 man-hours per minute; but the preplanning to allow accurate cutting from section to section of the orchestra is mandatory, unless only wide shots of the orchestra are used.

A symphony orchestra is no subject for the ad-lib camera work and directing which are necessary in small-station operation and will characterize most of the output of educational television stations.

# Influence of Echoes on Television Transmission

By PIERRE MERTZ

**Echoes in television transmission appear as irregularities in attenuation and phase characteristics. Tolerances on echoes well removed from the main picture are independent of the spacing (or echo delay). They vary inversely with spacing (echo delay) for close-up echoes. In the phase characteristic this leads to placing tolerances on envelope delay for large-scale features of the phase distortion, and on phase delay for fine structure irregularities. Tolerances are also placed upon the overall phase drift within the pass band. Similar treatment appears for the three classifications of attenuation distortion. Applications to broadcast and theater television are discussed.**

**I**N THE PROPAGATION of a television signal from one point to another it is, of course, necessary that such distortion as it undergoes should not unduly mar the final picture. One type of distortion which is relatively common consists in the generation of "echoes," or repetitions of a signal feature which come at times which are different from the original feature. This phenomenon can also be considered, from a different point of view, as a distortion in the steady-state amplitude response and phase characteristics of the transmission medium, taken as functions of frequency.

The present paper treats of the influence which such distortion has upon the

final viewed image, as the various parameters of the echo are changed. Conclusions are derived on how this sort of distortion may be described, and tentative ideas presented on how much of it may be acceptable.

The description and specification of this type of distortion are problems of some years' standing in the television art. Gannett and Green<sup>1</sup> in 1927, and Reynolds<sup>2</sup> (for a telephotograph rather than a television circuit) in 1936, each placed tolerances upon the envelope-delay distortion in the circuit. They also placed tolerances separately upon the amplitudes of distinguishable echoes in the circuit. The envelope-delay specification is one of the steady-state or spectral characteristics which describe the properties of the transmission process as a function of frequency. The echo specification can be characterized as a temporal characteristic, in which the properties are described by the changes in

Presented on October 6, 1952, at the Society's Convention at Washington, D. C. by Pierre Mertz, Bell Telephone Laboratories, 463 West St., New York 14. (This paper was received March 4, 1953.)

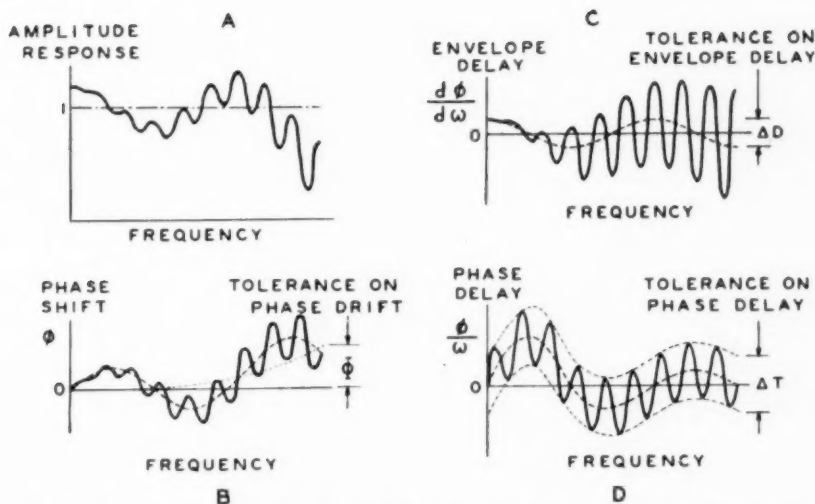


Fig. 1. Illustrative steady-state transmission characteristics. A, amplitude response vs. frequency; B, phase shift vs. frequency; C, envelope delay vs. frequency; D, phase delay vs. frequency.

transmitted signal as a function of time. The complete spectral characteristic is related to the complete temporal characteristic through a Fourier transform, and either is uniquely described by the other.

Logically it would therefore appear that a complete specification should be possible in one or the other type of characteristic alone. Descriptions of the specification in one or the other set of terms must of course be equivalent if they are to be valid, and preference for either can lie only in a greater simplicity of expression or use. The best understanding of the phenomena has come from free translation of the characteristics from one set of terms to the other, and back.

#### Summary

The simplest method of placing a tolerance upon some imperfection in a process consists of first finding a numerical quantity whose deviation from some value denoting perfection measures the amount of the imperfection. Then placing the tolerance simply amounts to

setting limits between which the quantity must lie for the result to be acceptable.

It has not so far been found possible to formulate a simple specification in such elementary terms to describe the imperfections caused by echoes or transmission irregularities upon a television image. What has been found feasible is to classify types of irregularities which occur. Tolerances are then applicable in different ways to the different classes of departure.

An illustration is given in Fig. 1. This shows at A an amplitude response and at B, a phase characteristic, each as a function of frequency. (That at B really represents a residual, after a linear component has been subtracted. This is to be explained in connection with Fig. 2.)

It is first necessary to distinguish large-scale features from the fine-structure irregularities. The process is illustrated for the phase plot at B. The large-scale features are indicated by the dashed line. The fine-structure irregularities, in the full line, oscillate about it.

Table I

Echo Delay Frequency Plot Structure	Short		Long	
	Coarse		Fine	
Tolerances	Cutoff drift	Excursions	0	Echo distortion 6 db/octave
Broadcast television				
4 mc, 525 lines	$\Phi$	$\Delta D = \Delta(d\phi/d\omega)$	$\Delta\phi$	$\Delta T = 6\Delta\phi/\omega_0$
Theater television				
8 mc, 740 lines	$\Phi$	$\Delta D/2$	$\Delta\phi$	$\Delta T/2$
8 mc, 525 lines	$\Phi$	$\Delta D/\sqrt{2}$	$\Delta\phi$	$\Delta T/\sqrt{2}$

It will appear in the detailed discussion that the large-scale features describe echoes which are close in to the original picture, or have a short delay with respect to it. The fine structure describes echoes that are remote from the original picture, or have a long delay. In the illustration, both of these, for simplicity, have been shown more regular than they would be found in practice.

A second classification of the fine-structure irregularities is then needed. It is to be noted whether the magnitude of the excursions is generally independent of the video frequency, or whether it shows a systematic growth with frequency. It is found that the first type describes echoes which are a clear replica of the original picture. The second describes echoes which form a less recognizable reproduction. The latter is the type illustrated in Fig. 1, and the growth shown with frequency is linear. It will appear in the discussion that this can be specified as growth at the rate of 6 db per octave.

The growth with frequency, or absence of it, is less significant for the large scale features, and for the present is to be ignored. However, here it is necessary to separate out the overall drift of the phase excursion throughout the frequency band. This is indicated by the fine dotted line in Fig. 1B.

These classifications are listed in the upper part of Table I. The remainder

of the table lists quantities which have been found useful as indices of the picture impairment due to the echoes. They can therefore serve as quantities upon which tolerances can be placed.

Consideration is for the moment to be confined to the entries for standard broadcast television, 4 mc, 525 lines.

The first quantity upon which a tolerance can be placed is the overall residual phase drift  $\Phi$  between zero frequency and the upper cutoff. It is indicated by the fine dotted line in Fig. 1B.

For the second quantity it is desirable to differentiate the phase characteristic of Fig. 1B to obtain the "envelope delay" (to be defined in connection with Fig. 4 below). The result is shown at C. A tolerance is then placed upon the envelope-delay excursions (or  $\Delta D = \Delta(d\phi/d\omega)$ ) in the coarse-structure components. These are shown by the dashed line in Fig. 1C.

The third quantity listed is applicable to undistorted echoes, and therefore cannot be used for Fig. 1. A case where it can be used is illustrated at the top of Fig. 8, where the fine-structure excursions do not increase toward high frequencies. Here the coarse structure is plotted as in the case of Fig. 1B, as a central dashed line. Then two parallel curves to it, as shown by the finer dashed lines, are drawn just far enough apart to bracket the peaks of the fine structure. The tolerance is placed upon the separation between the parallel curves, as a

measure of the fine-scale excursions. This is called  $\Delta\varphi$  in Table I. In practice the fine structure would be more irregular, and only the larger peaks would touch the parallel curves.

The fourth quantity listed is applicable to echoes distorted as in Fig. 1, where the fine-structure excursions increase in amplitude with frequency. For this case it is desirable to divide the phase shift in the characteristic of Fig. 1B by the radian frequency  $\omega$  to obtain the "phase delay" ( $\varphi/\omega$ , defined in connection with Fig. 4 below). This is shown in Fig. 1D, with the coarse structure again indicated by a central dashed line. Two parallel curves to it are drawn, as was explained above for Fig. 8. The tolerance is placed upon the separation between the parallel curves, as a measure of the fine-scale excursions in phase delay. This is called  $\Delta T$  in Table I. It will be shown in the discussion that it is related to the  $\Delta\varphi$  or the third quantity of the table. It is found experimentally to be roughly 6 times  $\Delta\varphi$  divided by the top radian frequency. This is listed in the table as  $6 \Delta\varphi/\omega_0$ .

As listed in the remaining items of Table I, for 8-mc 740-line theater television the tolerated excursions in the envelope delay  $\Delta D$ , or phase delay  $\Delta T$ , in microseconds, are halved. It will be seen in the discussion that this results from a proposal that the higher-grade image be designed to be good enough to be viewed from a closer relative distance than the broadcast television image. For 8-mc 525-line theater television these tolerated excursions in microseconds are by the same reasoning divided only by  $\sqrt{2}$  instead of by 2. For either number of lines the phase excursion tolerances  $\Phi$  or  $\Delta\varphi$  are unchanged.

Attention has been concentrated on the specification of tolerances for the excursions in the phase characteristics of Fig. 1B. Because of a correlation between the phase and amplitude characteristics, tolerances can be set upon the

amplitude characteristic in Fig. 1A and derivations from it in almost the same terms. In comparing the one to the other, nepers in the amplitude are analogous to radians in the phase. The quantities that are analogous to envelope and phase delay are not ordinarily used in connection with the amplitude characteristic. They can, however, be relatively easily computed, in exactly the same manner as for the phase characteristic.

The correlation mentioned is not a necessary one, and there are transmission systems in which it does not hold. A brief examination of such cases is given in the discussion on multiple echoes.

Such an analysis as is presented in this summary may appear unduly complicated. It is possible that in the future the complication may be reduced. In the present state of the art, the treatment given appears to be the simplest way of correlating the known experimental information on the matter.

Some numerical values should now be mentioned for the tolerances which have been presented. Such values depend of course upon the standard of image degradation which is deemed acceptable. In each case a range will be stated. The better pictures will be obtained with the tighter tolerances. The other end of the range, however, represents possibilities which are more likely to be obtained in the generally existing art. The values are given in terms of the phase characteristic, but are also applicable to the amplitude characteristic by replacing radians by nepers.

For the residual phase drift to cutoff, figures have been used ranging from  $\Phi \approx 0.20$  to 1 radian.

For the coarse-structure envelope-delay excursions the range of figures runs from  $\pm 0.15$  to  $\pm 0.75$  picture elements. A "picture element" is here taken as a half-cycle of the top effective video frequency. This leads to  $\Delta D \approx \pm 0.018$  to  $\pm 0.09 \mu\text{sec}$ .

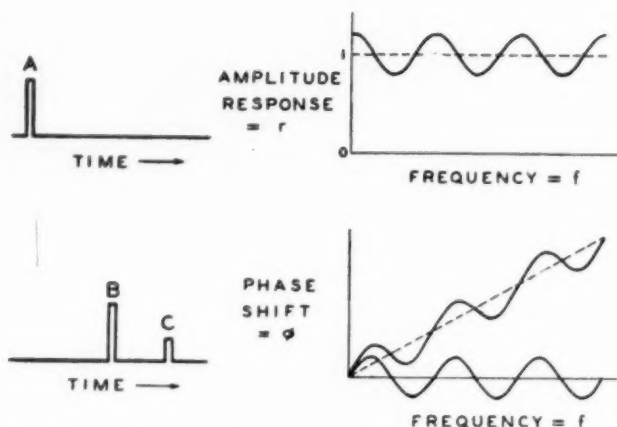


Fig. 2. Correspondence between echo and transmission characteristics.

For the fine-structure phase excursions the figures run from  $\Delta\phi \approx \pm 0.01$  to  $\pm 0.05$  radian.

For the fine-structure phase-delay excursions the figures run from  $\pm 0.02$  to  $\pm 0.1$  picture elements. This leads to  $\Delta T \approx \pm 0.0024$  to  $\pm 0.012 \mu\text{sec}$ .

One final point is needed before the summary is closed. In Ref. 1 a discussion is presented showing that the nature of the tolerances being considered changes at a video frequency equal to half the scanning line frequency. The present paper considers only the tolerances set on the characteristics above this dividing value. All discussion of tolerances is further confined to AM transmission of the signal.

#### Relations Between Echoes and Steady-State Transmission Characteristics

It has been recognized for some years that echoes in a signal transmission medium are revealed as irregularities in its steady-state transmission characteristics. These are sometimes called "linear distortions" because their relative value does not vary with signal level. A simple statement of these relations was presented in 1939 by H. A. Wheeler.<sup>3</sup> A brief recapitulation of the analysis is

given in the Appendix. The results are essentially summarized as follows:

1. A single echo appears as an array of ripples or sinusoidal scallops in both the amplitude response and phase characteristics.

2. The delay of the echo from the main signal influences the coarseness or fineness of structure of the scallops. The echo delay is inversely proportional to the wavelength of the scallops measured along the frequency scale in the plotted characteristics.

3. The amplitude of the echo, relative to that of the main signal, influences the amplitude of excursion of the scallops. The relative echo amplitude (if small enough) is equal to the peak-to-zero excursion in the amplitude response characteristic, measured in nepers. It is equal similarly to the phase shift peak-to-zero excursion, measured in radians.

4. There is a phase shift of  $90^\circ$  between the array of ripples in the amplitude-response characteristic and that in the phase characteristic. That is, the former are cosinusoidal, and the latter sinusoidal, ripples.

These properties are shown illustratively in Fig. 2. Here there appears schematically an original, sent picture

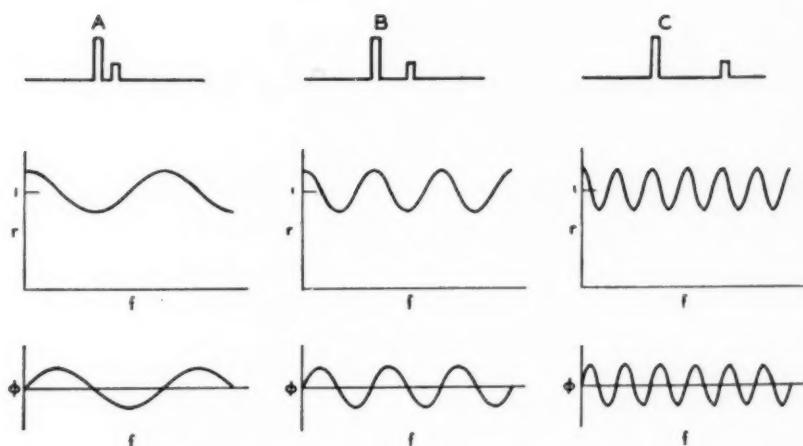


Fig. 3. Relation between echo delay and fineness of structure in transmission characteristics.

pulse at A, which is received as seen at B. An echo is shown also received at C. The corresponding steady-state or spectral amplitude response, versus frequency, appears at the upper right. Without the echo, the characteristic is as shown by the dotted line. The presence of the echo causes this to become scalloped according to the full line. At this point it is to be noted that many of the small figures such as those in Figs. 1 and 2 are illustrative only, and may not be exact in all their detail. No such liberties are taken, however, where actual data or large-scale plots are presented.

The phase-shift characteristic is presented at the lower right of the figure. Without the echo, the phase shift increases linearly with frequency, as indicated by the diagonal dotted line. According to the convention used in the Appendix, a positive value of  $\varphi$  corresponds to a phase retardation. With the echo there appears the sinusoidal scalloping about the dotted line, as illustrated by the full line.

The slope of the diagonal dotted line is a measure of the delay between signals A and B. For simplicity it is often desirable to ignore this, or to subtract it out.

Then the scalloping in the phase-shift characteristic oscillates about the  $x$  axis. This is also shown in the figure. Such a simplification was assumed for Fig. 1, and will continue throughout the present discussion.

There is illustrated in Fig. 3 the relationship between the closeness of the scalloping and the echo delay. The close-up echo at A leads to long sweeping scallops. As the echo at B is more delayed, the scallops get closer. A long-delayed echo, as at C, corresponds to fine-structure scallops.

Figs. 2 and 3 also illustrate the cosine-sine correlation between the scallops in the amplitude response and in the phase-shift characteristics. This relation was pointed out by H. W. Bode<sup>4</sup> in 1940. Because of it, further attention will be concentrated for the moment on only one of the characteristics, which will usually be the phase.

The phase-shift excursions in the characteristic may be measured directly on the characteristic itself. Fig. 4 illustrates phase-shift excursions in  $\varphi$  for a close-up echo at the left, and for a long-delayed echo at the right.

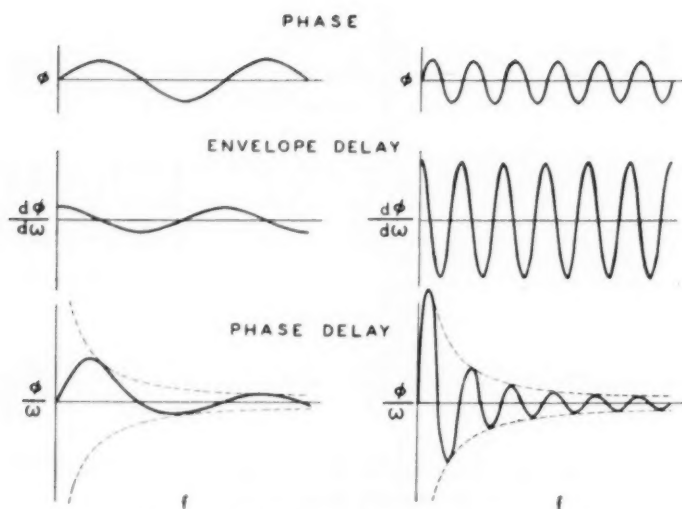


Fig. 4. Relation between phase characteristic, envelope delay and phase delay.

It is sometimes, however, convenient to use a quantity called the "envelope delay."<sup>6</sup> This is measured by the derivative  $d\phi/d\omega$ . Here " $\omega$ " denotes the radian frequency, or  $2\pi$  times the usual cyclic frequency  $f$ . The envelope delays are illustrated in Fig. 4. The derivative (as indicated in the Appendix) is proportional, not only to the amplitude of the scallops, but to their closeness of spacing. Thus, for the same amplitude of phase-shift excursions, the envelope-delay excursions are larger for the fine-structure scallops at the right than for the long sweeping scallops at the left.

Sometimes another quantity, called the "phase delay," is used.<sup>5</sup> This is measured by  $\phi/\omega$ . Thus the phase-shift excursions of the uppermost line of the figure are multiplied by the factor  $1/\omega$ . Hence the phase delay excursions appear within a pair of envelope lines  $1/\omega$  and  $-1/\omega$ . The envelope lines are far apart at low frequencies, and contract toward each other toward high frequencies. Plots of the phase delay for the two cases are illustrated at the bottom of Fig. 4.

Fig. 5 compares the phase excursions

and the envelope-delay excursions for three echoes, A, B and C. These are of equal amplitudes, but have different spacings from the original pulse. The phase excursions are shown at the left, and like the echoes, are of equal amplitudes. The envelope-delay excursions are shown at the right. They illustrate the influence of scallop structure on the derivative. That is, the envelope-delay excursions for the most close-up echo A are smallest. For the longest-delayed echo C they are largest.

In Fig. 6 are illustrated the excursions for three other echoes, A, B and C. These have the same delays as in Fig. 5, but their amplitudes have been taken unequal. They have been so chosen that the envelope-delay excursions for the three would be equal. This is shown at the right of the figure. Of course, correspondingly, the phase excursions are unequal, and proportional to the echo amplitudes. This is indicated at the left of the figure.

A simple conclusion appears from the examination of Figs. 5 and 6. This is that constant excursions in phase shift,

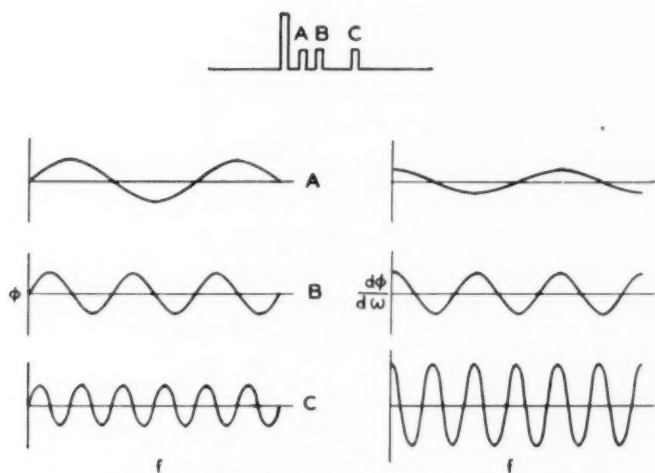


Fig. 5. Echoes proportioned to give fixed phase excursions.

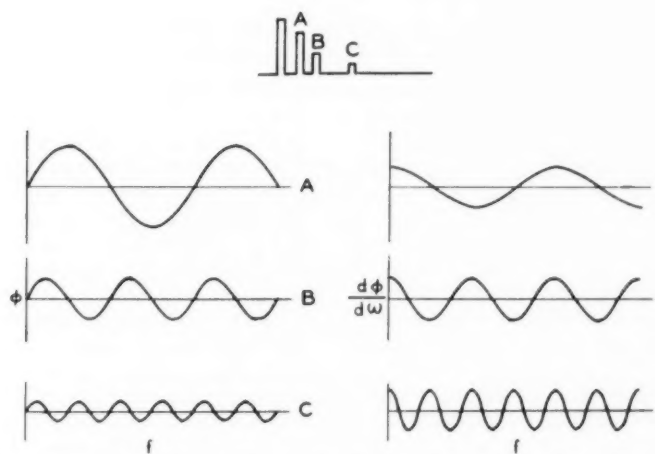


Fig. 6. Echoes proportioned to give fixed envelope-delay excursions.

irrespective of the fineness of structure of these excursions, correspond to constant echo amplitudes, irrespective of their delay. On the other hand, constant envelope-delay excursions, irrespective of their fineness of structure, correspond to echo amplitudes inversely proportional to their individual delays.

At this point we become interested in just how the eye rates echo imperfections. In particular we want to know how the impairing power of an echo varies with its spacing from the picture. Some brief summaries of experimental and other data are presented in Fig. 7. These indicate tolerances on echo

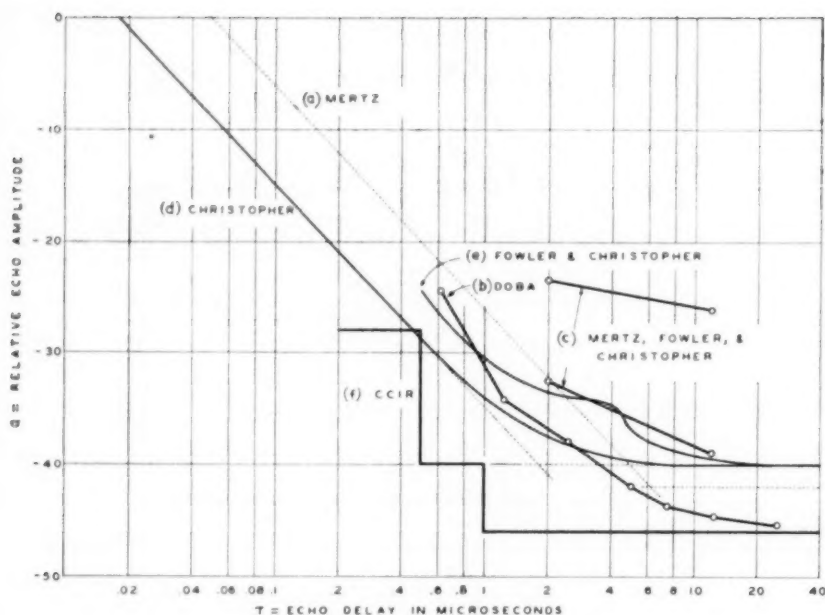


Fig. 7. Reported tolerances on echo amplitude as a function of echo delay.

amplitudes as a function of the echo delay. The data were taken on a variety of subject pictures, and under a variety of conditions. Except where stated otherwise, they were on broadcast television standards, or translated to these. A brief recapitulation of the sources, some of which are unpublished, is given here.

(a) *Mertz*.<sup>6</sup> A suggestion, based largely on experience with picture transmission, on the course to be expected of the tolerance as a function of echo delay.

(b) *Doba* (1949, unpublished memorandum). Relative values of tolerance indicated, adjusted toward crosstalk limit at long delays. Picture consisted of small solid rectangles on a flat field.

(c) *Mertz, Fowler and Christopher*.<sup>7</sup> Data on only two delays, summarized for two pictures. Figures are for echo "just perceptible" to median observers, and "impairment to picture, but not ob-

jectionable," or worse, to most critical 10% of observers.

(d) *Christopher* (1950, unpublished memorandum). Data covering pictures and engraved geometrical figures. Form of summary curve, taken as reasonably representative, smoothed from data.

(e) *Fowler and Christopher*.<sup>8</sup> Echo "just perceptible" to median observer. Single sensitive picture.

(f) *International Radio Consultative Committee*.<sup>9</sup> Limits recommended for overshoot and echoes. These are really for a 405-line 3-mc video band system.

Examination of Fig. 7 leads to the following conclusions.

a. The subject matter of the picture has an important influence on its vulnerability to echoes. In particular one of the pictures in the data summarized from Mertz, Fowler and Christopher is distinctly less sensitive than the other. In spite of this, the data for the more

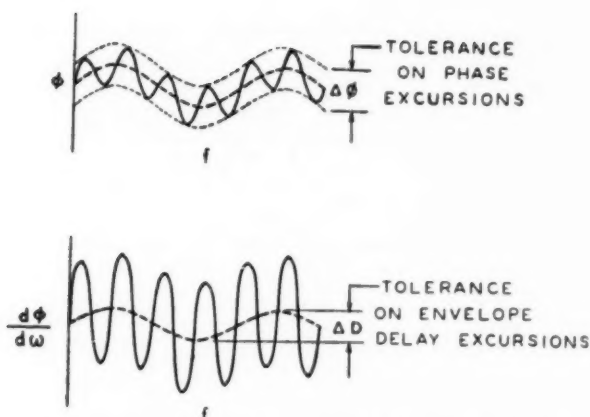


Fig. 8. Illustration of the method of placing tolerances on fine-structure and large-scale excursions.

sensitive pictures group together reasonably well.

b. The data tend to follow a trend surmised on the basis of experience with telephotograph transmission. The prolongation of the curve, summarizing the Christopher data, toward the shorter echo delays is not too certain from these experiments. It is drawn from rather scattered data, particularly on "negative" echoes. (In these, black in the original appears as white in the echo, and vice versa).

c. There is some indication of a trend, with the passage of time, toward tightening of the tolerances. The CCIR recommendations represent the most severe limits to date. In part, of course, this trend comes from a general improvement in picture quality and fidelity of contrast rendering.

The course of the curves mentioned in conclusion b above shows that large-amplitude echoes are tolerated when the echo delay is short, i.e., toward the left of the plot. As the echo delay becomes greater the permissible amplitude becomes much smaller, and finally tends to approach a fixed value. The apparent explanation is that when the echo is spaced close to the picture, it is in part

masked by it. In this region, therefore, the tolerance varies in an inverse manner with the spacing. Echoes that are spaced far from the picture, however, lose the effect of this masking. The tolerance on them becomes independent of the spacing.

This quickly leads to the further conclusion that the tolerance on close-in echoes toward the left of Fig. 7 can best be specified in terms of the constant envelope-delay excursions illustrated in Fig. 6, for which the echo amplitude varies inversely with echo delay. The tolerance on the remote echoes toward the right of Fig. 7 can best be specified in terms of the constant-phase excursions illustrated in Fig. 5, for which the echo amplitude does not vary with echo delay.

What this conclusion means in terms of the phase characteristic is indicated in Fig. 8. In the upper line there is illustrated a very simple case of a phase characteristic, in which occur both fine- and coarse-structure excursions. The derived envelope delay obtained from this characteristic is presented in the lower part of the figure. Here, as would be expected, the fine-structure excursions are relatively magnified, as compared to those in the phase shift.

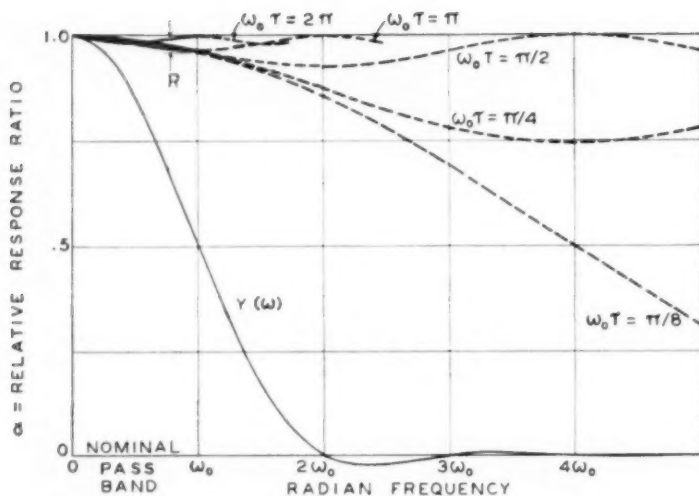


Fig. 9. Amplitude response characteristic for very close-in echoes.

In following up the conclusion which was just stated, the coarse structure, or long sweep average, of the envelope-delay characteristic is plotted in the dashed lines. The peak-to-peak amplitude of this average is then the quantity upon which a tolerance can be specified.

On the other hand, in the phase plot, in the upper part of the figure, parallel curves are drawn to the long sweep average. They are drawn just far enough apart to touch the peaks of fine-structure excursions. The tolerance can then be placed on the separation between the parallel curves.

#### Close-in Echoes, Merging Into Cutoff Shaping

The inspiration for the material in this section was drawn from the unpublished memorandum of S. Doba, which forms item (b) of the sources for the data of Fig. 7. The treatment given here, however, is simpler and rather less sophisticated than that used by Doba.

It was noted in Fig. 3, that the closer in the echo, the wider is the sweep of the scallops, along the frequency scale,

which are observed in the transmission characteristics. When the separation amounts to one picture element, only a half-cycle of the scallop is left, within the range of the nominal passband.

This situation is illustrated in Figs. 9 and 10. The  $\omega_0\tau$  in these refers to the quantity used in the Appendix, equation (14), to measure the echo delay. When  $\omega_0\tau = \pi$ , the echo delay is one picture element. The curve  $Y(\omega)$  in Fig. 9 is illustrative only and indicates the relative amplitude response which corresponds to a signal element of the "raised cosine" type, where the nominal video passband ranges from 0 to  $\omega_0$  (in units of radian frequency).

From both Figs. 9 and 10 it is noted that when the echo delay is 0.5 picture element, the nominal passband ranges over only one quarter-cycle of the scallop. When the delay is 0.25 element, the range covers only one-eighth cycle; and when it is 0.125 element, the range is only one sixteenth-cycle. Thus for these very short echo delays, such a small portion of the scallop cycle is covered in the passband that the nature of the influence on the transmission characteristic is

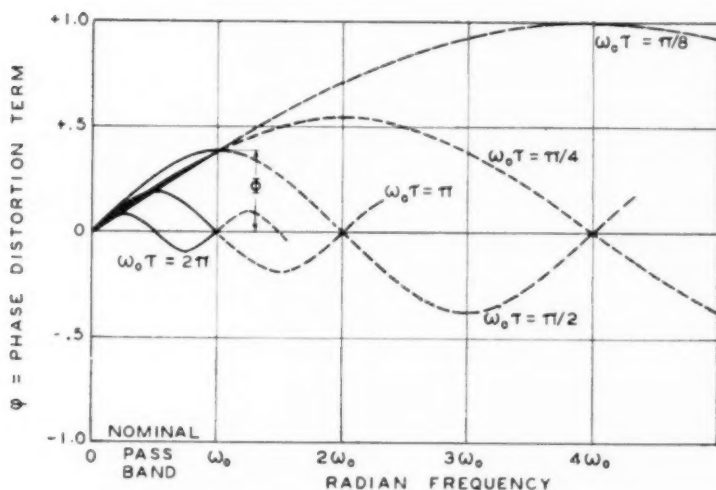


Fig. 10. Phase characteristic for very close-in echoes.

changed. It is no longer simply describable as a dentellation or scallop on the characteristic. It becomes more obviously a change in the trend of the characteristic (either the relative response or the phase shift) toward the cut-off frequency.

The effect of this inclusion of only a fraction of the scallop wave in the pass-band reaches further. It affects the relationship between the magnitude of the echo and the excursions in the characteristics. It is clear from examination of Figs. 9 and 10 that a measured excursion over the nominal passband under certain conditions is considerably less than the excursion of the complete sinusoid or cosinusoid.

A purely geometrical diagram of what this amounts to, for the relative amplitude-response and phase characteristics, is illustrated in Fig. 11. In the upper auxiliary diagram at the extreme left, the quantity  $aF$  represents the double excursion in the amplitude-response characteristic for the frequency band extending up to  $\omega_0$ . This compares with the double excursion  $2a$  which would be obtained for the same echo amplitude,

but over a frequency band extending over at least a half-cycle of scallop. It is clear from the figure that the numerical ratio  $F$ , between the two, diminishes gradually from the value 2 to zero, as the band to  $\omega_0$  reduces, from covering a half-cycle of scallop down to zero. This course of the numerical ratio  $F$  is indicated by the heavy full line in the lower or main diagram of Fig. 11. It has the value 2 where the echo delay is one picture element, or  $\omega_0\tau = \pi$ , for which the band covers a half-cycle of scallop, and diminishes toward zero as this is reduced.

A similar auxiliary diagram is shown in the upper right of Fig. 11 for the phase-shift characteristic. Here the numerical ratio is called  $G$ , and its value is 2 when the band to  $\omega_0$  covers  $\frac{3}{4}$  cycle of scallop. As  $\omega_0$  moves to the left  $G$  diminishes to 1 at the point where a half-cycle of scallop is covered, and further motion of  $\omega_0$  to the left then brings the ratio gradually to zero. The course of  $G$  is indicated by the thin solid line in the lower main diagram of Fig. 11. It is seen to be broken into segments according to the explanation.

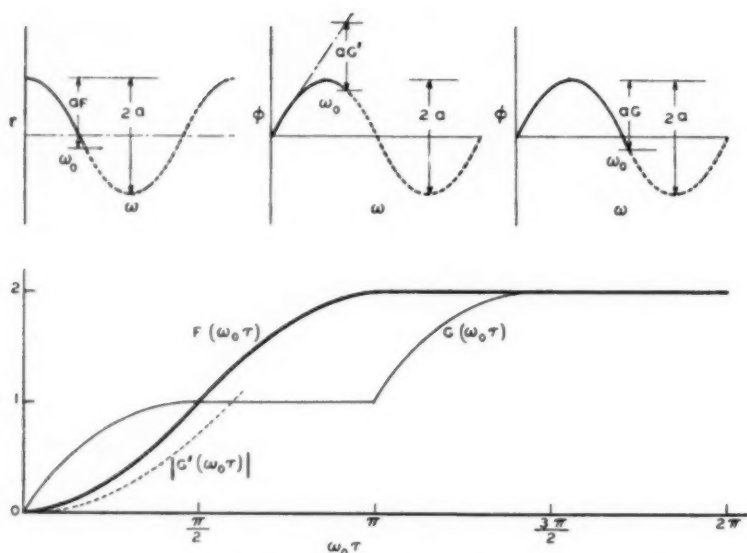


Fig. 11. Relation between excursion of characteristics and echo amplitude for very close-in echoes.

A further point to be noted on Figs. 9 and 10 is that, as the scallops assume a longer and longer wavelength (corresponding to a closer and closer-in echo) the course of the characteristic within the nominal passband approaches more and more closely a fixed type. Thus the entire course of the characteristic within the nominal passband can be specified more and more closely by a single number. Such a number can be simply the excursion in the characteristic at the upper cutoff.

If this is so, then, in a signal confined to the frequency spectrum of the passband, it would be impossible to distinguish between the effects of a small-amplitude longer-delayed echo, and a suitably chosen larger-amplitude shorter-delayed echo. The computation for choosing the amplitude for the variously delayed echoes is illustrated in the following equations. Here  $R$  represents the double excursion in the relative amplitude-response characteristic as shown in

Fig. 9, and  $\Phi$ , that in the phase-shift characteristic as shown in Fig. 10. The equations come from the auxiliary diagrams of Fig. 11.

$$\begin{aligned} R &= aF(\omega_0\tau) \\ \Phi &= aG(\omega_0\tau) \end{aligned} \quad (1)$$

Hence the amplitudes  $a$  are:

$$\begin{aligned} a &= R/F(\omega_0\tau) \\ a &= \Phi/G(\omega_0\tau) \end{aligned} \quad (2)$$

The amplitudes  $a$  are those which have been used for adjusting the curves for the various echo delays in Figs. 9 and 10 to give the constant excursions  $R$  and  $\Phi$  at cutoff. Since the functions  $F$  and  $G$  in Fig. 11 are not identical, it is clear that a simultaneous adjustment with a single amplitude at each echo delay is not possible for both Figs. 9 and 10. That is, the two amplitudes  $a$  computed from equation (2), one for Fig. 9, and the other for Fig. 10, will differ somewhat. The functions  $F$  and  $G$ , however, have much the same trend with echo delay.

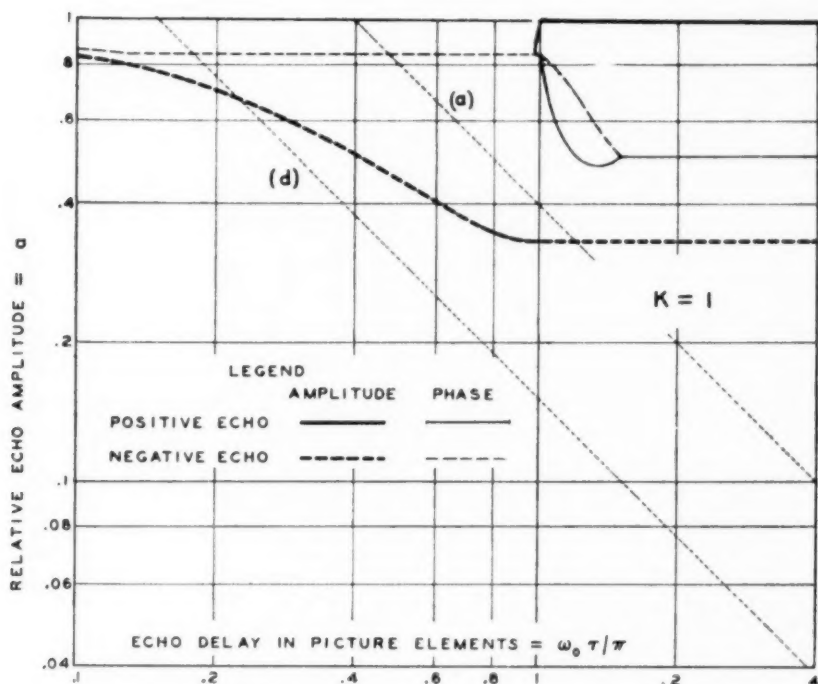


Fig. 12. Relation between echo amplitude and echo delay for double-excision  $K = 1$  in characteristic.

Thus a compromise value of  $a$  is possible for each echo delay plotted in Figs. 9 and 10, to permit approximate constancy in the resulting excursions  $R$  and  $\Phi$ .

A further point is to be noted in the application of equations (2). This is that, at very short echo delays, the major part of the phase distortion consists of a linear component proportional to frequency. In practice this linear component would be interpreted as merely that much more (or less) undistorted delay in the system. Thus it would be subtracted out, and only the residual curve (which is approximately a cubic) would be kept as a measure of the phase distortion.

The question of exactly what to subtract, over the range of echo delays, is not easy to answer categorically. It is

clear that for the larger echo delays, where there are several cycles of scallop, the linear component of the scallop close to zero is not significant, and nothing should be subtracted. In order to avoid entering into difficult mathematics, only a simple rule will be used here. The curve, with linear term subtracted, is shown as the fine dotted curve  $G'(\omega_0 \tau)$  in Fig. 11. It is derived from the middle auxiliary diagram at the top of the figure. Here the phase excursion  $aG'$  is taken with respect to the initial linear component of the scallop as shown by the dot-and-dash line. It is seen to be negative, and its absolute value is plotted in the lower diagram. As the fraction of the cycle used (or echo delay) increases  $G'$  rapidly becomes large and crosses curve  $G$ , for which no subtraction of

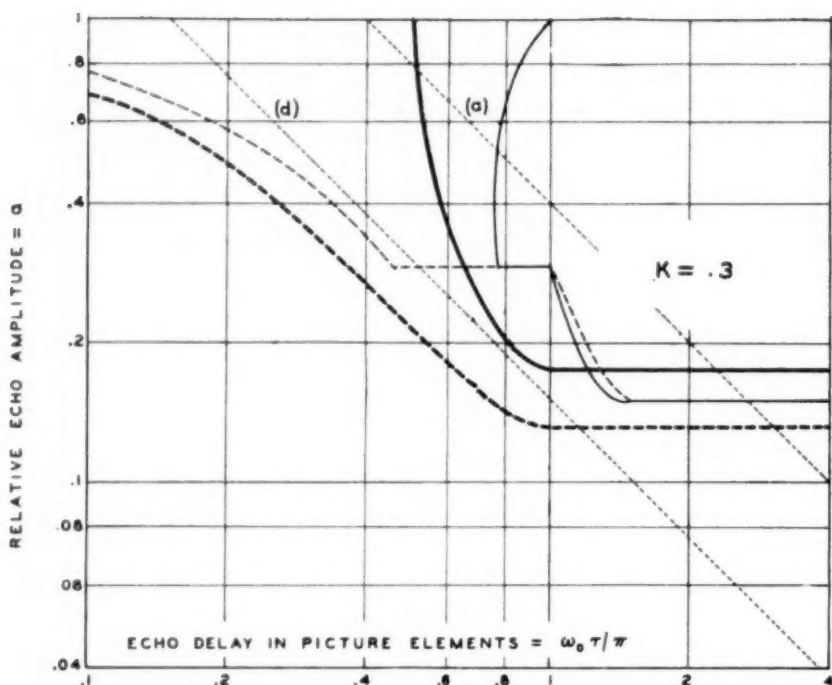


Fig. 13. Relation between echo amplitude and echo delay for double-excursion  $K = 0.3$  in characteristic.

linear term has been effected. The simple rule is that  $G'$  will be used on the shorter echo delay side of the intersection, and  $G$  will be used on the longer echo delay side.

To recapitulate the discussion, it appears that the description of a very short-delayed echo in terms of response and phase characteristics up to the cut-off frequency is a function of some combination of echo amplitude and echo delay. Approximately, at least, the description is independent of either parameter alone, provided that the other varies in a suitable inverse manner in the combination.

If the description is thus independent, it means that the distortion caused in any given signal is similarly independent, and further, that the picture impairment

caused in any given picture by this signal distortion is similarly independent.

Thus the relationship in the combination between echo amplitude and echo delay describes the required variation of the former as a function of the latter to result in a constant picture impairment. This was, of course, exactly the aim of Fig. 7, and it is now possible to consider the expectation, from the largely geometrical considerations which have been developed, of the course of the curves in that figure toward the very short echo delays.

The relationship described is obviously that of the equations (2). Since  $R$  and  $\Phi$  are taken as constants, the course of  $a$  is the reciprocal of the compromise course of the functions  $F$  and  $G$ , respectively. At this point it is desirable,

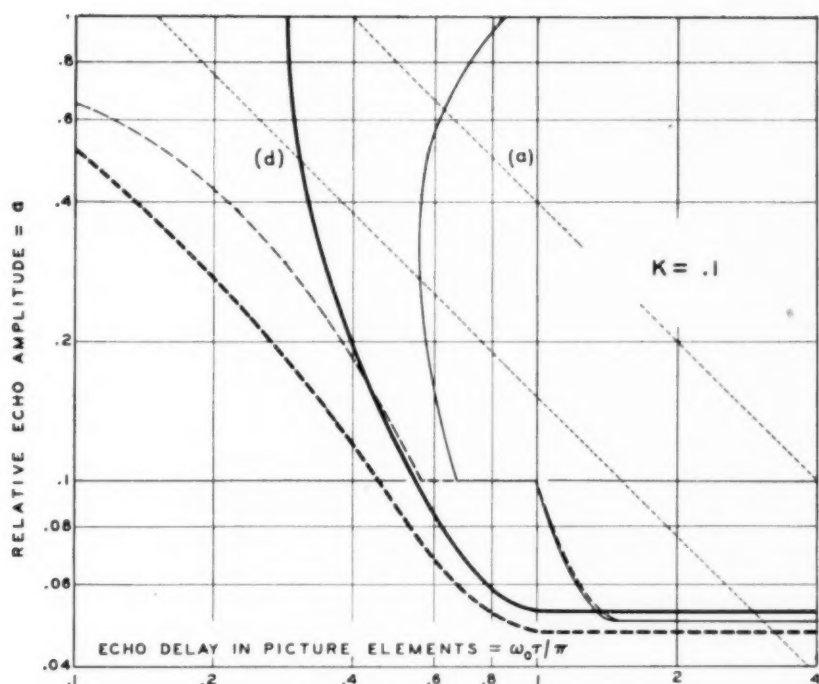


Fig. 14. Relation between echo amplitude and echo delay for double-excursion  $K = 0.1$  in characteristic.

however, to leave the approximate equations (9) and (11) of the Appendix, upon which equations (2) are based, and use the exact equations (8) and (9). This is because in this region of echo delays  $a$  tends to become large. When the exact equations are used, the shape of the curve for  $a$  is affected, as well as its magnitude, by the constant values chosen for  $R$  and  $\Phi$ .

These relationships have been plotted in Figs. 12, 13 and 14. The figures illustrate the echo amplitudes, for various echo delays, that are set by a fixed excursion in transmission characteristic within the nominal passband. In Fig. 12 this double excursion is set at  $K = R = 1$  for the amplitude response, and at  $K = \Phi = 1$  radian for the phase. In

Fig. 13 it is set at  $K = 0.3$ , and in Fig. 14 at  $K = 0.1$ .

In the plots the relationship presented between echo amplitude and echo delay is not the compromise which was mentioned earlier in the discussion. A separate figure for  $a$  is in each case derived, respectively, from equations (8) and (10) of the Appendix. The use of the exact equations causes a further complication. In the approximate equations (2) the results are the same regardless of whether the assumed echo is positive or negative. When the exact equations are used this is no longer the case, and separate plots have been made for positive and negative echoes in Figs. 12, 13 and 14.

The trend of the curves in Fig. 12 is rather complicated because of the large

**A. DISTORTIONLESS ECHO**

**B. DIFFERENTIATED ECHO**

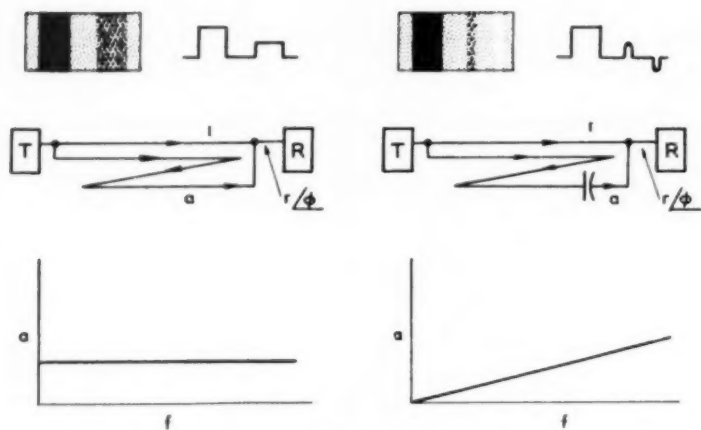


Fig. 15. Comparison between distortionless and differentiated echoes.

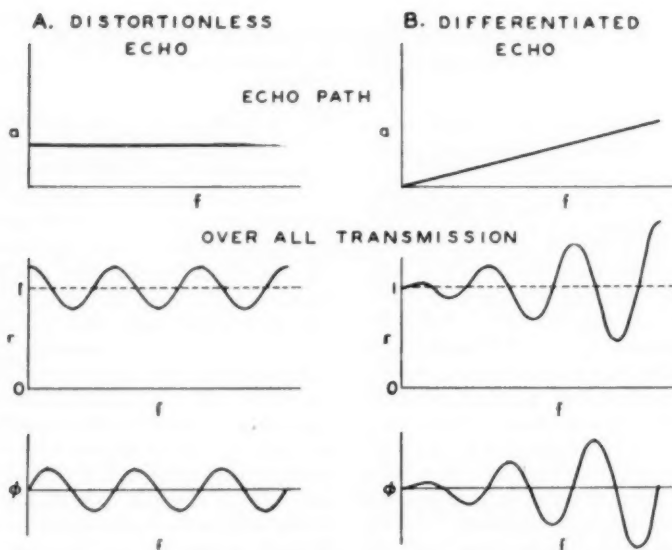


Fig. 16. Overall transmission characteristics describing distortionless and differentiated echoes.

values of  $a$  involved, and it is advantageous to study the other two figures first. The trends in Figs. 13 and 14 follow, at least in a rough fashion, the continuation of the experimental and other data of Fig. 7 toward short echo delays, as summarized by the lines (a) and (d). These lines are drawn in the later figures with those designations. The departures of the curves, for positive echoes running generally above, and for negative echoes running generally below the diagonal line, correspond remarkably to the more or less scattered observations reported in the unpublished memorandum of Christopher listed as source (d), Fig. 7.

The conclusion drawn from the above is that for the very short echo delays the tolerance can be set effectively upon the amplitude or phase-characteristic excursion, from zero frequency to upper cutoff. The value of  $K$ , or measure of this double excursion in amplitude response or radians, is chosen to make the curves approximately tangent to the diagonal line. From Fig. 13 and the trend indicated by the other two figures it would appear that to merge with line (d) should set a value of  $K$  at 0.25 to 0.20. The merger occurs at an echo delay near one picture element. Toward somewhat greater echo delays from this point the experimental and other tolerances plotted in Fig. 7 can no longer be specified in terms of a fixed excursion  $R$  or  $\Phi$  within the nominal passband. They follow instead the diagonal lines (a) and (d). These are specified in terms of an envelope-delay tolerance, as was developed in connection with that figure. There is some sensible region over which specification in one set of terms or the other leads to about the same result. Thus the exact point of demarcation selected for a setting of tolerances is not critical.

The one picture element at which the transition comes corresponds to the inclusion of a half-cycle of the scallop, on the transmission characteristics within the nominal passband (see Figs. 9 and

10). Thus it is on a structure of this order, or coarser, that the tolerance on the phase drift of Fig. 1B is to be applied. Correspondingly, it is on a structure of this order, or finer, that the tolerance on the envelope-delay excursions of Fig. 1C would apply.

### Influence of Distortion in the Echo

Up to this point the detailed discussion has considered only undistorted echoes. By these are meant echoes representing a sharp and clear displaced representation of the original picture. Distorted echoes, in which the displaced image is not sharp and clear, are, however, quite common. An illustration of a simple type of distortion is presented in Fig. 15. Here the distortionless echo is shown at the left for comparison. The echo is indicated as coming from an extra transmission path between transmitter and receiver. The extra path takes a longer transmission time than the main path. For a distortionless echo the amplitude response  $a$  over the extra path, is flat over the frequency range.

The case of the distorted echo is shown at the right. Here the extra path has a response of a type which could be obtained from a small series capacitance. The amplitude response, as indicated at the bottom, is directly proportional to frequency. In a logarithmic frequency plot it would have a slope of 6 db per octave. Such a type of response leads to a differentiation of the echo. This is indicated schematically at the top right of the figure.

It is of interest to compare the overall phase and amplitude characteristics of paths having distortionless and differentiated echoes. This is done in Fig. 16. The response over the echo or extra path is repeated at the top of the figure. This response curve forms an envelope for the scallops in both overall amplitude and phase. At the left are repeated the curves which have been shown earlier. At the right the scallops are seen to have

# A. UNDISTORTED ECHO

# B. DIFFERENTIATED ECHO

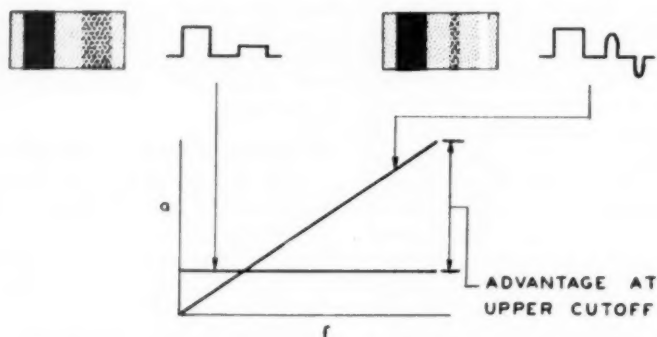


Fig. 17. Differing amplitudes of undistorted and differentiated echoes that are equally perceptible.

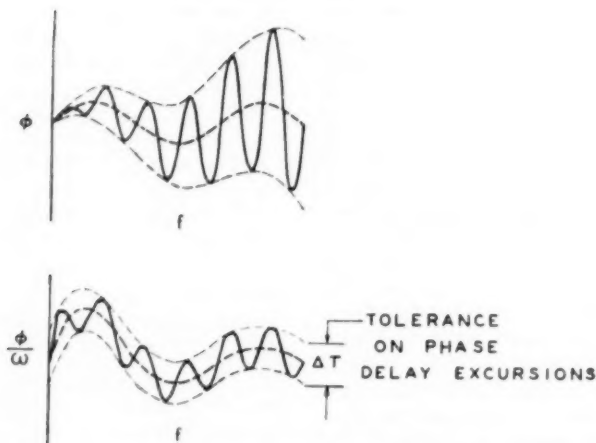


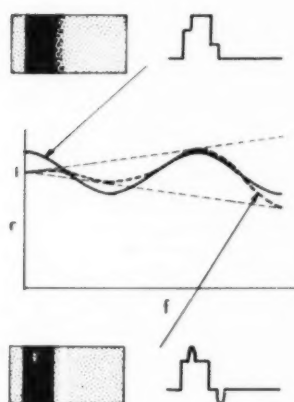
Fig. 18. Tolerance on phase delay for differentiated echoes.

progressively increasing excursions with frequency.

At this point we may consider how the eye compares a differentiated with a distortionless echo in its capability of impairing the picture. Diagrammatically the two are illustrated in Fig. 17. It is found that at the cutoff frequency a substantially larger response is permitted for the differentiated than for the undistorted echo. This is called the "ad-

vantage at upper cutoff" in the figure. Some experimental determinations of this quantity are reported in the Mertz, Fowler and Christopher reference already noted.<sup>7</sup> A tabulation is given herewith of the echo attenuation required for the median observers for a just perceptible echo, as plotted in two figures of that paper. The attenuation is measured in each case at 4 mc.

A. CLOSE-UP ECHO



B. LONG-DELAYED ECHO

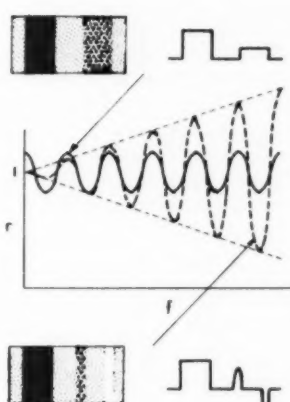


Fig. 19. Comparison of tolerances for close-up and long-delayed echoes.

The data are not, of course, wholly complete since the delays of the two longer-delayed echoes differ. However, for the present a generally typical value of the advantage can be taken as 15 db, or a 6-to-1 amplitude ratio.

It will be recalled, from Fig. 4, that in the phase-delay characteristic the amplitude of the scallops of phase excursion is reduced toward higher frequencies. This suggests the possibility of obtaining a characteristic which describes the differentiated echo of Figs. 15 to 17, with excursions which do not vary over the frequency range. Such a characteristic would be convenient for specifying the tolerance.

An illustration of the idea is shown in Fig. 18. At the top this indicates a simple phase characteristic with both coarse- and fine-structure excursions. The latter correspond to a differentiated echo and, therefore, increase in amplitude with frequency. At the bottom the corresponding phase delay is plotted. The  $\omega$  in the denominator just cancels the growth with frequency of the fine-structure excursions. This then permits the use of the fine-structure excursions in phase delay as a quantity upon which a

Table II. Echo Attenuation and Delay

Fig. No. in Ref.	Flat		Differentiated		Adv., db
	(db)	( $\mu$ sec)	(db)	( $\mu$ sec)	
15	23.8	(2)	8.5	(2)	15.3
	26.0	(12)	9.5	(6)	16.5
16	32.5	(2)	21.0	(2)	11.5
	39.0	(12)	23.5	(6)	15.5

fixed tolerance (independent of frequency), can be placed.

The treatment just considered for differentiated echoes applies when they are well separated from the original picture. An illustration of the comparison with the case when they are close up is shown in Fig. 19. The case for the remote echoes already considered is shown at the right. Here large excursions are permitted toward the upper cutoff of the characteristic for the differentiated echo (illustrated at the bottom) as compared with the excursions for the undistorted echo (illustrated at the top). Table II indicates that the advantage reduces as the echo comes closer up. While complete data are

not available for the more close-up echoes, the general indications are that the advantage for the differentiation becomes very much smaller. For the present considerations the advantage will be taken to become substantially negligible. Consequently the tolerance on the long sweeping excursions is taken as constant over the frequency range.

Other classes of echo distortion than differentiation can be considered. That discussed, however, is generally typical, and others will not be explored here.

#### Cumulation of Echoes

The discussion so far has included only the very simple cases of a single echo, or two echoes quite far apart. In practice such a situation is likely to be rare, and the numbers of echoes from different sources and having various delays may be expected to be found.

The simplest method of dealing with them is to assume that they add at random, both as signal amplitudes and as sinusoidal ripples in the amplitude and response characteristics. If this is the case, both signal amplitudes and ripple amplitudes cumulate on a root sum square basis. The tolerances then can logically be set in the same manner as before, but on the cumulated instead of the individual amplitudes. In practice, however, the tolerances are usually set on maximum rather than on rms (root mean square) excursions. The ratio of peak to rms amplitudes tends to increase as a number of sinusoidal ripples of different periodicities are added together. Hence there is some tendency for the maximum excursion to cumulate faster than the rss (root sum square) echo amplitude.

An examination of possible systematic factors in the cumulation of echoes has been made by Fowler and Christopher.<sup>8</sup> The first case comes when the echoes occur closely together. In the extreme situation the signal amplitudes add arithmetically instead of on a rss basis. It is similarly found that the subjective per-

ceptibility also adds faster than on the rss basis. Where the echoes which come close together are each close up to the original picture the ripple amplitudes in the transmission characteristics follow closely the same shape regardless of the echo spacing, as was indicated in Figs. 9 and 10. They tend therefore also to add arithmetically rather than on the rss basis. Thus tolerances set on the cumulated excursions continue consistent, whether for single or multiple echoes.

Where the echoes coming close together are all far from the original picture, the tendency for the ripple amplitudes in the transmission characteristics to add arithmetically continues, but not so markedly as for the closer-in echoes. Thus the excursions may cumulate somewhat more slowly than the subjective effect.

The second case of a systematic factor comes when the echoes are well separated from each other. In the extreme situation the echoes tend to become independent. Complete independence would mean that the insertion of the additional echoes would not degrade the picture beyond the effect of the echoes already existing. Here the excursions cumulate somewhat faster than the subjective effect. This influence becomes less pronounced as the echo level is raised and as more echoes are cumulated.

For general engineering purposes the law of random cumulation and use of the peak excursions probably represent the most useful simple guide to the tolerances to be applied. Where there is opportunity for a more detailed analysis of the echoes this evaluation may be found conservative or liberal according to the specific situation and may be revised to suit.

A specific case of multiple echoes comes about when all the excursions come in only the amplitude-response or phase-shift characteristic and the other is smooth and flat. As was developed in Ref. 3, and indicated in the Appendix,

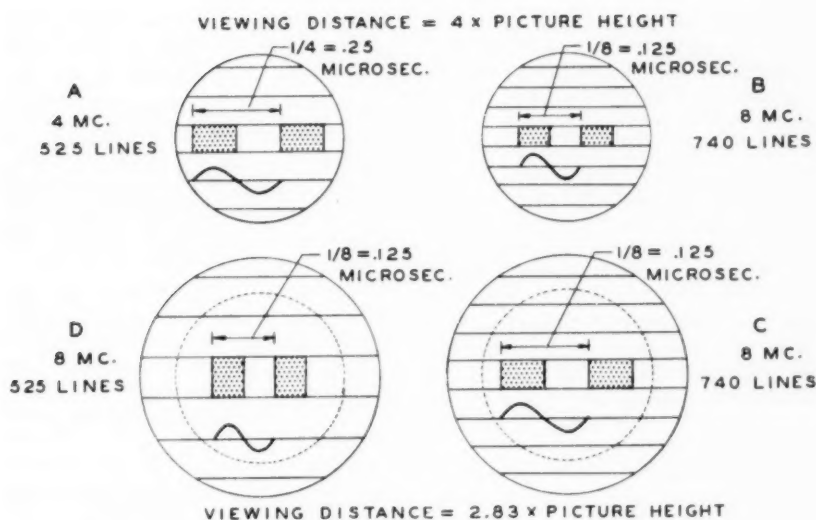


Fig. 20. Comparison of picture elements for broadcast and theater television.

this situation corresponds to a pair of echoes. One is leading and the other lagging, with respect to the original picture, and the two separations are equal. Also the echo amplitudes are equal, and each is half that of the single echo which results when an appropriate scalloping is then placed upon the smooth characteristic. If the two echo amplitudes of the pair are added on an rss basis, the effective amplitude is  $\sqrt{2}/2 = 1/\sqrt{2}$  units, for unit excursion in the one characteristic, with zero excursion in the other. The effective amplitude of the single echo is one unit, for unit excursion in each of the two characteristics. Thus one can say in such a situation that the effective echo is proportional to the excursions in amplitude response and phase characteristics added in quadrature (i.e., on an rss basis). This gives a procedure which can be used in the case of transmission systems which do not show the correlation which has been mentioned between amplitude and phase excursions.

#### Tolerances for Theater Television

All of the general discussion which has been given above applies equally well to broadcast or theater television. However, the experimental data which are cited in the plot of Fig. 7 and Table II above were taken on pictures which used the broadcast standards. It is of some interest to consider how the tolerances compare in the two fields, so that the figures can be developed for the theater application.

The shape and size of a picture element for a 4-mc broadcast television picture is illustrated at A in Fig. 20. This shows an enlargement of a small part of the field of view. The scanning lines are sketched in and a picture element is taken along one of these, as a half-cycle of the highest effective video frequency (sketched below it). The element, therefore, has a duration of half the 0.25- $\mu$ sec periodicity of this frequency. The element, hence, has a 0.125- $\mu$ sec duration. A similar view is shown at B for a possible 8-mc 740-line theater television picture.

The finer detail permitted in the second picture is exemplified by the narrower spacing between scanning lines, and by the shorter dimension of the picture element along the scanning line.

The tolerance to be put on the echoes depends in part, as was already noted, upon their spacing from the original picture. Before proceeding to evaluate these comparatively in A and B of the figure, we can note a suggestion made by the author in 1951 for a similar comparison in the tolerance on random noise.<sup>10</sup> This suggestion was to the effect that allowance for the improved quality of the theater television be reflected in the engineering of the tolerances. Specifically it was proposed that the tolerance be engineered on a closer viewing distance for the better picture. The ratio suggested was 1 to  $\sqrt{2}$ .

In the present case this would enlarge the image area at B to that shown at C. Here the picture elements then become of exactly the same size and shape as those seen at A. If the field of view in the magnified area is cut down in the diameter ratio of  $\sqrt{2}$  to 1 as indicated by the dotted circle in C, the picture becomes identical to A.

If we apply the suggestion, it means that all tolerances which have been set on envelope or phase-delay excursions can remain the same if the tolerances are measured in picture-element durations. If the tolerances, however, are measured in microseconds, they will be halved for the 8-mc band as compared with their values for the 4-mc band.

The tolerances on phase-shift excursions where applicable are not a function of echo spacing and are therefore not changed in going from broadcast to theater television.

These deductions have so far assumed a 740-line theater television. If the latter uses the broadcast standard 525 lines, with an 8-mc band, the magnified field of view becomes that shown at D in Fig. 20. Here the picture-element

height as measured by the scanning-line spacing is greater than in C in the ratio of  $\sqrt{2}$  to 1. In compensation, the picture element width is narrower than in C, in the ratio of 1 to  $\sqrt{2}$ . This last correspondingly narrows down the geometrical spacing of all echoes and permits increases in the tolerances on envelope- and phase-delay excursions in the ratio of  $\sqrt{2}$  to 1.

This result indicates a certain advantage for the choice of a smaller number of scanning lines in the picture. Such an idea is not new, and was one of the factors discussed when the standards were set for broadcast television.<sup>11</sup>

## Appendix

Consider a Fourier component of the signal voltage of frequency  $\omega/2\pi$ :

$$v = \cos \omega t \quad (3)$$

When this is transmitted through a distortionless system, which however delays it by the time  $T$ , it becomes:

$$v = \cos \omega (t - T) \quad (4)$$

If the system also transmits an echo of the signal, of relative amplitude  $a$ , and relative delay  $\tau$  to it, the distorted signal becomes:

$$\begin{aligned} v &= \cos \omega (t - T) + a \cos \omega (t - T - \tau) \\ &= \cos \omega (t - T) + a \cos \omega (t - T) \cos \omega \tau \\ &\quad + a \sin \omega (t - T) \sin \omega \tau \end{aligned} \quad (5)$$

$$= (1 + a \cos \omega \tau) \cos \omega (t - T) + a \sin \omega \tau \sin \omega (t - T) \quad (6)$$

The overall transmission, including the echo, can be interpreted as:

$$v = \alpha(\omega) \cos [\omega t - \varphi(\omega)] \quad (7)$$

where  $\alpha(\omega)$  gives the overall amplitude ratio and  $\varphi(\omega)$  gives the overall phase shift. These quantities are computable from equation (6), and are particularly simple when the relative echo amplitude  $a$  is small. That is:

$$\alpha = [(1 + a \cos \omega \tau)^2 + (a \sin \omega \tau)^2]^{\frac{1}{2}} \quad (8)$$

$$\approx 1 + a \cos \omega \tau \quad (9)$$

$$\varphi = \omega T + \tan^{-1} \frac{a \sin \omega \tau}{1 + a \cos \omega \tau} \quad (10)$$

$$\approx \omega T + a \sin \omega \tau \quad (11)$$

The approximate equations (9) and (11) indicate that the description of the echo in the overall transmission characteristics consists of a ripple or scallop which is cosinusoidal for the amplitude and sinusoidal for the phase. While the exact equations (8) and (10) do not indicate precisely the same shape of ripple, its general features are little different. The approximate equations indicate that the ripple amplitude, in nepers or radians, is equal to the relative echo amplitude  $a$ .

The wavelength of the ripples, along the radian frequency scale, is the change in  $\omega$  which causes a change of  $2\pi$  in the argument  $\omega \tau$ . Hence

$$\Delta \omega = 2\pi / \tau \quad (12)$$

or

$$\Delta f = 1 / \tau \quad (13)$$

In particular call  $\Delta f = f_0 = \omega_0 / 2\pi$  when it extends from zero frequency to the effective upper video cutoff. One half-cycle of frequency  $f_0$ , or  $\tau_c = 1 / (2f_0) = \pi / \omega_0$ , then defines one picture element. Any echo delay  $\tau$  can be measured in picture elements  $\tau_c$ , as:

$$\tau / \tau_c = \tau / (\pi / \omega_0) = \omega_0 \tau / \pi \quad (14)$$

The envelope delay,  $d\varphi/d\omega$ , from equation (11) is:

$$d\varphi/d\omega = T + a\tau \cos \omega \tau \quad (15)$$

The amplitude of the ripples in the envelope delay is  $a\tau$ . This is proportional to the echo amplitude  $a$ , and inversely proportional to the ripple wavelength  $\Delta f$  or  $1/\tau$ .

The phase delay  $\varphi/\omega$ , is:

$$\varphi/\omega = T + (a/\omega) \sin \omega \tau \quad (16)$$

If to the signal of equation (5) there is added a second echo of the same amplitude as the first, but leading the original signal by time  $\tau$ , that equation becomes:

$$v = \cos \omega(t - T) + a \cos \omega(t - T - \tau) + a \cos \omega(t - T + \tau) \quad (17)$$

$$= (1 + 2a \cos \omega \tau) \cos \omega(t - T) \quad (18)$$

Thus the pair of echoes is described by transmission characteristics having a ripple only in the amplitude, and no distortion whatever in the phase.

If the second echo is given an amplitude which is the negative of the first, equation (5) becomes:

$$v = \cos \omega(t - T) + a \cos \omega(t - T - \tau) - a \cos \omega(t - T + \tau) \quad (19)$$

$$= \cos \omega(t - T) + 2a \sin \omega \tau \sin \omega(t - T) \quad (20)$$

With this pair of echoes the ripples in the transmission characteristics add in the tangential direction, and cancel in the radial direction (in the complex plot). Thus first order ripples appear in the phase, but cancel in the amplitude. When the echoes are small enough, therefore, they are described by a ripple in the phase and only infinitesimal distortion in the amplitude. When the echoes are large there is a second-order ripple in the amplitude which is not cancelled. It requires more than a pair of echoes to correspond to a characteristic which shows no distortion whatever in the amplitude.

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## Erratum

A. V. Loughren, "Recommendations of the National Television System Committee for a Color Television Signal," *Jour. SMPTE*, 60: 321-336, Apr. 1953.

Page 326, column 1, line 10:

*For:* harmonics of the scanning-line frequency.

*read:* harmonics of one-half of the scanning-line frequency.

# Applications of High-Speed Photography in Rocket Motor Research

By FLOYD G. STRATTON and KURT R. STEHLING

**Hazards and conditions in research on rocket engines have established high-speed photography as a useful tool. High-speed cameras have removed personnel and sensitive equipment from dangerous areas. The camera's independence of the rocket engine permits an unbiased record of firing behavior and often yields clues to anomalous occurrences not otherwise explainable. The application of high-speed photography to transparent rocket thrust chamber research is emphasized; some specialized variations of normal schlieren and shadowgraph techniques are described, as are the studies of hydraulic transients.**

## General Applications

When a rocket motor is fired from a fixed "tie-down" position in a test cell, the primary objective is to obtain information regarding the operation of the motor. This is often a complex and difficult problem because of the extreme dangers to instruments and personnel.

Corrosive acids mixed with highly combustible fuel under extremely high pressures are some of the hazards that exist during firing. Malfunctions of the equipment can result in dangerous explosions. Therefore, one of the primary requirements for firing conditions is safety to personnel and protection for valuable recording equipment.

Presented on October 10, 1952, at the Society's Convention at Washington, D.C., by Floyd G. Stratton and Kurt R. Stehling, Bell Aircraft Corporation, P.O. Box 1, Buffalo 5, N.Y.  
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Test cells are made of thick concrete walls with small portholes of bullet-proof glass which permit safe observation of the motor firing. The test engineers would like to be able to see more, without exposing themselves unnecessarily to the hazards involved. Therefore the high-speed camera has proved an excellent tool for obtaining a record of certain phases of rocket firings. For example, cameras can be synchronized easily to record the start or shutdown phase of a rocket motor operation.

It has been found that running the cameras at approximately 1000 frames/sec was sufficient to permit recording the combustion phenomena, and at the same time to have a fairly long running time for high-speed cameras. An average running time of approximately 5 sec has been obtained. This short camera operating time left much to be desired, since most firings lasted longer, in some cases, several minutes. This, of course,

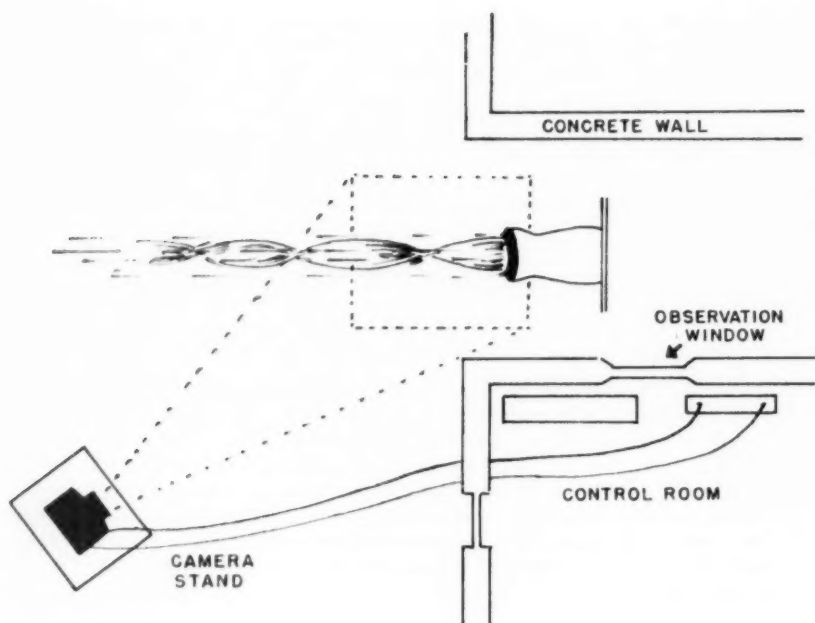


Fig. 1. Diagram of setup for a rocket firing.

precluded complete coverage of the firing period. However, it has been possible to record several malfunctions and rough firings when they occurred within the 5-sec limits of the camera running time.

High-speed movies made of the flame area immediately following the throat exit have revealed a chain of shock-wave patterns which pulsate according to conditions of the firing. A smooth run was indicated by a steady row of shock waves which maintained a stable pattern. A rough run was evident by a very pronounced oscillation of the shock patterns. The more violent oscillations could possibly have led to destruction of the motor. Often, the behavior of the shock-wave pulsations yielded a clue to the cause of the malfunctions and supplied data which supplemented that obtained by other means of instrumentation recording.

Usually one of the biggest problems in

making high-speed motion pictures is the adequate illumination of the subject, in order to register on the high-speed motion-picture film. In this case, the subject was self-illuminated by a brilliant white-hot flame and exposure was probably the least of the problems. Usually, it was necessary to stop the lens down. Most of the exposures were made on a fast panchromatic negative film with the camera running speed set at 1000 frames/sec at  $f/11$  to  $f/16$ . This exposure is maintained regardless of the time of day or weather conditions prevailing.

Setting up a camera for a rocket firing was a difficult procedure. Most of the camera setups were made at about a  $45^\circ$  angle to the exit of the throat of the motor from about 30 to 60 ft away (see Fig. 1). The camera was mounted on a rigid stand made of angle iron and tubular steel with a flat top about  $14 \times 20$  in. supported by a ball socket. The top



**Fig. 2. Camera operator setting up the camera preparatory to firing.**

could be tilted and locked in any angle up to  $45^\circ$  from horizontal. After the camera was aligned and focused it was loaded with film and covered with a heavy box made of boiler plate with a window cut out in front of the lens.

When the box was locked into position, a thick bullet-proof laminated glass plate about  $1\frac{3}{4}$ -in. thick was placed in position in the window opening.

All wires to the camera were strung from the camera stand to the control room without touching the ground, since the concrete ramp was constantly flooded with a deluge of water to dilute the concentrated acid that might spill in the test area.

The camera operator had to wear rubber clothing from head to foot while setting up the camera preparatory to firing (Fig. 2.). When setup procedures were completed, and after the rocket motor system was loaded with propellant and

pressurized, the cameraman vacated the area. Frequently a single motor involved scores of man-hours for preparation of the test. Yet the camera setup time usually had to be limited to an hour or less, just prior to firing.

In order to insure perfect camera performance it became necessary to follow a check list for each setup. The uncomfortable clothes and the hazards involved often led to nervous fatigue causing the cameraman to forget to throw a switch or set the camera properly, in his desire to leave the area as quickly as possible. Because of this, the camera setup check list often proved indispensable.

During winter, when low temperatures prevailed, it became necessary to install a strip heating element inside of the camera box to keep the camera warm during the indefinite waiting periods prior to the rocket motor firing. Several

times the cameras have stood for hours at below 0 F temperature waiting for a firing to commence, yet on the signal to fire the cameras performed faithfully.

Wind direction was another important factor which had to be considered. Whenever possible, a location was chosen out of the path of corrosive acid fumes blowing toward the camera position. This was necessary for the protection of the camera as well as for visibility. The acid clouds were thick enough to obscure the vision of the flame if they hung too long in the direct line from lens to subject.

Synchronization of the camera to obtain the start or shut-down phases of the firing was controlled from the master control panel by the test engineer, by arrangement of a suitable electrical circuit.

#### Research Applications

The theory and practice of liquid-propellant rocket thrust-chamber design has been partially based on empirical data, often extrapolated or adopted from "conventional" combustion-engine data.

With the postwar increase in the development of rocket thrust chambers has come an increase in some of the characteristic problems of these engines. Similarly, the adoption of new propellants (as compared with the "classical" liquid-oxygen and alcohol combination) has added to these problems. Some of the undesirable behaviorisms commonly met with in thrust-chamber-operation combustion are rough burning or "instability," low combustion efficiency and propellant ignition delays leading to explosive starting transients.

The relative significance and mechanism of the interactions between the liquid propellants injected into the combustion chamber, the actual combustion processes and the chamber geometry are not yet fully understood.

"Normal" instrumentation, such as pressure transducers, thrust recorders, flowmeters, and thermocouples ordin-

arily suffice to indicate the various fluid and combustion parameters which serve as a measure of the motor's behavior. However, when conditions such as unexplainable rough burning occur, and when the cause cannot be ascertained from the parameters measured with this instrumentation, other avenues of research must be explored — not only for the alleviation of the undesirable characteristic, but also for the gathering of new facts which could serve as a foundation for continuing motor development. High-speed motion-picture photography is one of the new but promising tools employed for this purpose.

A rocket thrust chamber or "motor" consists essentially of a propellant injector and a throat cylindrical chamber. This serves as a container for the combustion of the liquid propellants, which enter at high velocities through the injector. The pressure and temperature in a typical chamber may reach 300 psi and 2600 K. At the throat the pressure is lower while the hot combustion gases are exhausted at sonic velocity and then expanded to the atmosphere in a nozzle, reaching supersonic velocity.

Since the motor seems so uncomplicated, an obvious method of studying the combustion in the chamber would be the construction of a transparent chamber which could permit the direct viewing of the burning pattern within. This has, in fact, been attempted by several investigators<sup>1</sup> within the last few years.

Severe design and operating difficulties were encountered — mostly due to the high chamber pressures and temperatures and sometimes erosive qualities of the propellants (in some cases aniline and red-fuming nitric acid). Due to mechanical and optical problems flat-sided chambers were usually built, or narrow strip inserts of Pyrex or quartz<sup>2</sup> were located at strategic points in the wall. Strangely enough, Plexiglas walls proved most suitable (when "normal" photography only was desired) since the very high chamber temperatures melted

the surface of this plastic, forming a liquid film which radically reduced the rate of heat transfer and left the main body intact. Furthermore, the relatively plentiful and inexpensive Plexiglas permitted the construction of motors larger than the usual 100 lb thrust small-scale research types.<sup>3</sup>

Useful knowledge about injector and flame behavior was obtained with these Plexiglas motors with high-speed motion-picture photography (black-and-white and color). Flame pulsations and uneven combustion patterns were readily detected, in at least one case, and were related to a particular type of injector.<sup>3</sup> The cameras used in this work were Eastman Type III, 16mm motion-picture at 3000 fps. Film speeds were measured by noting the movement of a timing disk shown on each frame or by using film timing pips. Kodak Super XX black-and-white and Kodachrome color film were used.

Berman and Logan<sup>2</sup> of General Electric photographed rocket motor combustion through a  $\frac{1}{4}$ -in. quartz slit using either a 16mm, 8000-fps camera or a General Radio Co. Type 651 35mm continuous strip with a 2-in. focal-length lens at film speeds of 8 to 80 fps. The flame front velocity was readily measured this way.

In order to obtain a more rigorous and detailed picture of the events in the rocket combustion chamber it was decided at Bell Aircraft Corp. to develop a schlieren or shadowgraph method of combustion analysis. It was believed that the inherent sensitivity and resolving power of the shadowgraph method would permit the detection and analysis of the fluid stream-to-vapor-to-gas mechanism. This in turn would lead to a fuller understanding of the effect of fluid interaction with the actual combustion gases and could possibly indicate remedial measures in the case of rough combustion. Furthermore, the path of vapor recycling and turbulence might be detected.

Pilot studies were undertaken with a miniature propane-air motor which roughly simulated normal motor burning. The basic research on the optical alignment, photographic techniques, chromatic and polarigraphic schlieren methods and glass employment was done with this motor. The transparent walls consisted of  $2 \times 4 \times \frac{1}{4}$ -in. pieces of Vycor glass. The optical system for normal shadow studies consisted of two  $f/6$ , 12-in. dia front-surface parabolized mirrors, a 100-w zirconium arc point light source and rotating prism camera. Several preliminary attempts were made to improve upon normal schlieren or shadow techniques. Two of these consisted of polarigraphic control of background light intensity, using two crossed Polaroid filters, one in front of the light source and the other in front of the camera. Another was the positioning of two adjoining color filters (in this case, red and green) at the normal location of the knife edge. The junction served as a knife edge or block for on-axis rays, while all off-axis rays, deviated by the differential refraction within the chamber, passed either through the red or green filter. This yielded a schlieren image whose color striae indicated the direction of deviation of the light rays.

Since it was desired to obtain shadowgraph information quickly, the above methods were temporarily suspended for the conventional methods. A series of shadowgraph and schlieren motion pictures at 1000 fps was then obtained with a small 8-in. flat-sided motor with Vycor walls. The lens settings used were usually  $f/1.5$ . Operating difficulties with a small motor of this type and constant breakage and blowout of the Vycor walls prevented a full utilization of the inherent possibilities of the schlieren method. However, enough information on the behavior of the structure and combustion process was obtained to warrant further research in the field.

Some of the difficulties remaining are:  
(a) Differentiation between background and flame light.

(b) Obtaining the largest possible image per frame with existing lenses.

(c) The prevention of over- or under-exposure, usually the former.

(d) Adaptation of the optical system of the camera to that of the optical schlieren system.

(e) Coordinating the optical speeds of the schlieren system with that of the camera and film.

(f) Minimizing vibration and optical misalignment in an area subject to the former.

(g) Protection against corrosive fumes and high temperatures, etc.

Studies were also made of the fluid-flow behavior and mixing rates of the spray of the rocket motor injector. In general, it can be said that propellant entry sequences and mixing rates were determined with dyed water (yellow and blue) and elaborate solenoid camera starting devices. These latter were necessary since the fluid was injected into the atmosphere at 150 fps.<sup>4</sup>

#### Summary

Properly protected, the rotating-prism type cameras have proved to be excellent recording mediums for short periods during rocket motor testing.

However, it has seemed desirable that cameras of larger film capacity and longer running times be designed for this particular application. For example, it would be more advantageous to have a 20-sec capacity.

It is felt that only a beginning has been made and that many more applications can be found for the high-speed camera in rocket motor research and development.

The authors acknowledge the assistance of Mr. C. Kurland in some of this work and the cooperation of various members of the Bell Aircraft Corporation Rocket section.

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# Simple Electronic Devices for High-Speed Photography and Cinematography

By P. FAYOLLE and P. NASLIN

**Described are a basic electronic flash and delay circuit and its applications to shadow and reflected-light photography, Kerr-cell shutters and ultra-high-speed cinematography in conjunction with the Cranz optical setup.**

**E**LECTRICAL METHODS of high-speed photography and cinematography are by no means new. More than 70 years ago Mach and Cranz used the electrical spark to photograph bullets and shock waves with exposure times of the order of 1  $\mu$ sec and thus founded experimental ballistics. In 1903, at the Marey Institute, Paris, Lucien Bull analyzed the flight of insects at rates of several thousand frames/sec. His rotating-drum camera triggered a spark-gap via a rotating switch and an induction coil. He thus established a long-unbroken record in high-speed cinematography at a time when normal-rate motion pictures were hardly born. He later achieved rates of many thousand frames/sec, using a relaxation high-voltage discharge circuit and a rotating-mirror camera. No notable progress was made

until 1929, when the Cranz-Schardin multiple-discharge circuits and optical setup made it possible to obtain a few dozen high-definition pictures at rates up to several million frames/sec.

The achievements of these and other pioneers in the field are perhaps more remarkable than anything achieved since, because they had accurately to initiate and control high-voltage phenomena by purely electrical means, without the help of fast-response and flexible electronic devices.

The French Central Laboratory of Armaments in Paris also took part in the development of the methods of spark photography between World Wars I and II. P. Nicolau and P. Libessart,<sup>1,2</sup> both generals today, used them successfully for wind-tunnel work and for the investigation of ballistic phenomena. This work was continued during the German occupation of France by the authors of this paper, under cover of industrial research such as the study of vibrations and failure of mechanical parts.

Since VE Day, we have been faced with the task of providing our research

Presented on October 8, 1952, at the Society's Convention at Washington, D. C., by P. Naslin, who read the paper, and P. Fayolle, Laboratoire Central de l'Armement, Place St. Thomas d'Aquin, Paris, France.

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**Fig. 1.** Shadowgraphic exposure of an 8-mm rifle bullet in flight, with a velocity of approximately 1950 fps; flash duration at half maximum amplitude is 0.1  $\mu$ sec, effective time of exposure much shorter. The bullet is breaking a glass plate with a zig-zag metal coating, thus generating the timing pulse.

establishments and proving grounds with modern experimental equipment in the fields of dynamic pressure recording, short-time measurement and high-speed photography. The nature of this task accounts for the special features of the instruments to be described below. In accordance with the views expressed by Dr. W. A. Wildhack,<sup>3</sup> of the National Bureau of Standards, in his opening lecture to the Instruments and Measurements Conference held in Stockholm in 1949, we hold that "instrumentation has now become an art of its own." The development and use of scientific and technical instruments should therefore be handled by separate groups of workers. A corollary to this statement is that the instruments should be as easy as possible to manufacture, to handle and to maintain; hence their main features should be simplicity, ruggedness, reliability and flexibility. Also, and for obvious reasons, their cost should be as low as possible. It is clear that electronic instruments using as far as possible commercially available radio components should, if properly designed, fulfill all the above requirements.

#### **Electronic Spark Generator for Single Shadowgraphic Exposures**

This instrument was primarily developed for use with the shadowgraphic optical method using the Libessart pinpoint spark-gap, although, as will be mentioned later, it may also be used in

a schlieren setup or even for low-energy reflected-light exposures.

No particular effort was made concerning the discharge circuit proper. Since the early days of spark photography it has been a well-known fact that the combined use of a high-charging voltage, a small low-inductance spark condenser and short leads makes it possible to reduce the actual flash duration\* to  $10^{-7}$  sec or less. With operation under adequate optical conditions, the duration of the photographically active portion of the flash, as measured by the optical blur due to the motion of the subject, may be reduced to  $10^{-8}$  sec. The picture quality that can be obtained is demonstrated in Fig. 1, which shows an 8-mm bullet in flight. The discharge circuit used, comprising a 0.004  $\mu$ f ceramic condenser produced by the United Insulator Co., a British firm, had a natural frequency of 30 mc/sec. There would be no point in improving these performances any further, since other limitations are set by the finite dimensions of the pinpoint spark-gap, diffraction phenomena, grain size of the photographic material, etc.

Figure 2 shows our standard pinpoint spark-gap assembly, of the Libessart type. The steatite insert with a hole

\* The flash duration is arbitrarily defined as the time during which the light-vs.-time curve is above its half-maximum amplitude.

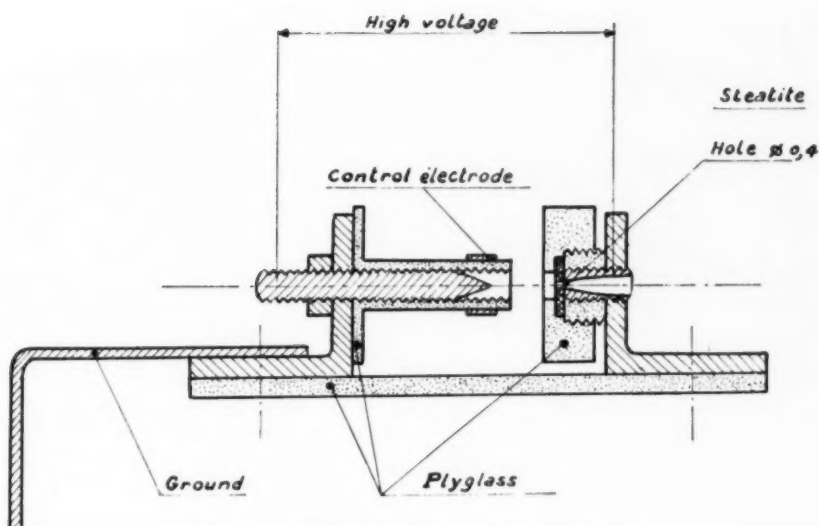


Fig. 2. Modified Libessart pinpoint spark-gap.

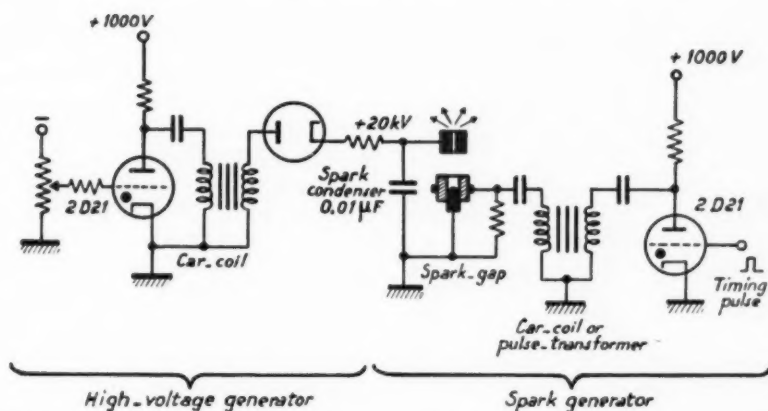
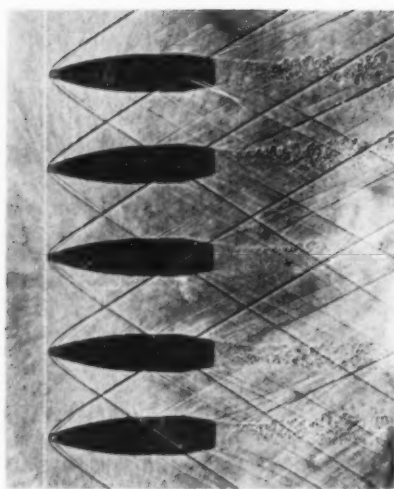


Fig. 3. Circuit diagram of spark generator for single shadowgraphic exposures.

about 0.5 mm in diameter is essential: it guides the discharge channel so that light may be effectively emitted through the anode hole. Nevertheless, the light source is not a perfect uniformly illuminated circle; there is always a maximum of brightness at some random point on the edge of the anode circle. The

discharge is initiated by applying a 15-kv pulse to the control electrode, which takes the form of a ring insulated from the anode by a plyglass cylinder.

In order to reduce as much as possible the self-inductance of the discharge circuit, the spark-gap assembly is mounted directly across the spark



**Fig. 4. Superimposed shadowgraphs of five 8-mm rifle bullets with photo-electric triggering. The photographic plate was shifted vertically after each shot. Triggering time-lag:  $1 \mu\text{sec} \pm 0.1 \mu\text{sec}$ .**

condenser. Our standard voltage is of the order of 20 kv. According to the desired light output, the condenser capacity is fixed between 0.001 and  $0.1 \mu\text{f}$ , thus yielding an electrical energy between 0.2 and 20 j. The desired performance determines whether the units are equipped with ordinary paper capacitors made by the Société Industrielle des Condensateurs, or with more expensive paper capacitors produced by Philips especially for use with flash sources. For an energy of 2 j corresponding to a capacity of  $0.01 \mu\text{f}$  the natural frequency of the discharge circuit is 1 mc for the ordinary type, while with the special type the discharge is almost aperiodic and the voltage falls to 1% of its initial value within  $0.1 \mu\text{sec}$ . The discharge can be made fully aperiodic if a 5-ohm damping resistor is inserted into the circuit.

Whereas, as mentioned before, no marked progress has been made as far as exposure time is concerned, the advent of electronic triggering methods has made it possible to improve the timing accuracy by two or three orders of magnitude, thus eliminating one of the greatest difficulties of earlier methods of ballistic photography.

Figure 3 shows the circuit arrangement of our standard unit. The 20-kv generator consists of a thyatron relaxation oscillator, an automobile ignition coil and a rectifying diode. The high voltage may be varied by changing the thyatron grid bias and, hence, the recurrence frequency. Triggering consists in applying a 15-kv negative pulse to the spark-gap control electrode. This triggering pulse is generated by a thyatron and a transformer. In accordance with the required timing accuracy, the latter is either an auto coil or a pulse transformer with a rise time of  $0.1 \mu\text{sec}$ . The overall time-lag between the application of the timing pulse to the thyatron grid and the flash is of the order of  $1 \mu\text{sec} \pm 0.1 \mu\text{sec}$  with the pulse transformer and 10 times as much with the automobile coil. This timing accuracy is illustrated in Fig. 4, which shows five 8-mm rifle bullets recorded on the same photographic plate shifted vertically after each shot.

A complete unit, with a paper condenser and a triggering auto coil, may be seen in Fig. 5, with both covers removed. The  $25 \times 35 \times 25$  cm cabinet houses the power supply, the high-



Fig. 5. Spark generator for single shadowgraphic exposures, with covers removed.

voltage generator and the triggering circuit. The projector unit, mounted on a stand, contains the spark-gap and the spark condenser. The only noncommercial component is the heater transformer for the rectifying diode, which is insulated to ground for 20 kv. Several dozen units of this kind have been constructed at an approximate cost of \$700 each.

In the units now under production, the relaxation high-voltage generator has been replaced by the standard high-frequency 22-kv generator made by Philips for television applications.

Before leaving this subject, it may be of interest to say a few words about the high-accuracy triggering method used before pulse transformers were available, which may still be useful for laboratory work. In this method (Fig. 6) the triggering thyatron plate was capacitance-coupled to the spark-gap trigger electrode. The latter was insulated from the cathode by an annular air gap. With its 2.5-kv plate voltage, the thyatron life was limited to about 300 flashes, which was adequate if none of them was wasted during adjustments. The flashes needed for adjusting the optical setup

were initiated by short-circuiting the thyatron by means of a relay-controlled mechanical switch. The main disadvantage of this triggering method was the rather critical nature of its adjustment.

For most applications the timing pulse is derived from the observed phenomenon by means of a suitable transducer, e.g., a photoelectric cell, a crystal microphone, a solenoid, etc. If necessary, it is delayed an appropriate period before being applied to the triggering thyatron control grid (see below).

The unit may be used for schlieren and reflected-light photography if a suitable light source is substituted for the pinpoint spark-gap. The krypton tubes C and D of Fig. 7, through which 2 j may be dissipated in a few tenths of a microsecond, are particularly useful for schlieren photography, because the discharge takes place in a narrow cylindrical channel. Xenon tubes A and B withstand a 20-j discharge and yield a light output sufficient to photograph a 60 sq ft surface from a distance of 10 ft with an  $f$ /number of 3.5. These tubes, whose breakdown voltages are relatively low, are normally mounted in series with a triggering spark-

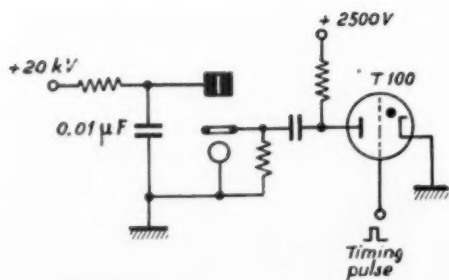


Fig. 6. Triggering method without transformer.

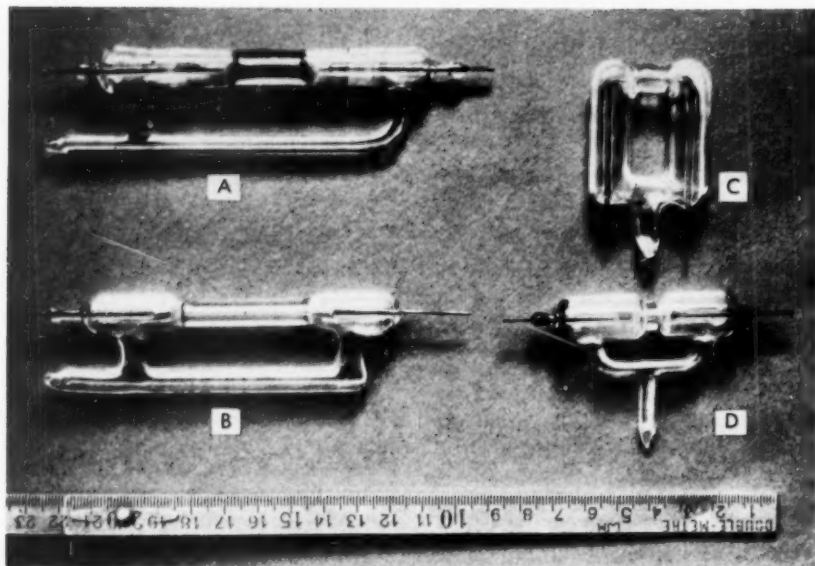


Fig. 7. Gas discharge tubes. A, B — xenon tubes for 20-j discharges. C, D — krypton tubes for 2-j discharges.

gap. Triggering may be assisted by pulsing a few turns of wire wound outside the glass envelope.

#### Spark Generator for Single Reflected-Light Exposures (Defatron)

Front-light illumination of a large surface requires a powerful light output. Fortunately, the flash duration may be much longer than for shadowgraphic or schlieren pictures of small objects; the sharpness of the picture is not defined by the absolute value of the blur,

but by its ratio to the subject dimension in the direction of motion. For instance, if an exposure time of  $0.1 \mu\text{sec}$  is necessary to obtain a good picture of an 8-mm rifle bullet, an exposure time of  $1 \mu\text{sec}$  will be quite adequate for an 80-mm artillery shell. A flash duration of  $1 \mu\text{sec}$  is in effect adequate for most applications where a large light output is needed. Very few commercial gas-discharge tubes, if any, fulfill these requirements; they also have for us the double disadvantage of being rather

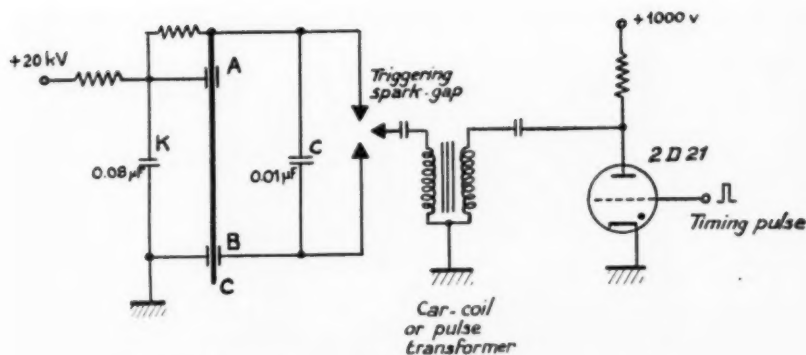


Fig. 8. Circuit diagram of Defatron guided-spark generator.

expensive and not being made in France. Our Defatron,\* based on a principle worked out by Prof. Schardin's team at St. Louis, France, is an inexpensive light source combining a powerful light output with a flash duration of  $1 \mu\text{sec}$ .<sup>4,5</sup>

The Defatron projector shown diagrammatically in Fig. 8 embodies a so-called "guided spark" with a dissipation of about 200 j at 22 kv. The spark-gap comprises two annular main electrodes A and B, 10 cm apart, outside an insulator in which a control electrode C in the form of a rod is inserted. If 22 kv are applied between A and B, no breakdown occurs. The discharge is initiated by grounding C, which is connected to A through a large resistor. The high-voltage gradient between A and C causes an intense ionization of the air at the surface of the tube in the vicinity of A. The resulting positive ion sheath then acts as a virtual anode, which grows until it reaches the cathode B, when breakdown occurs. Electrode C is grounded via a triggering three-electrode spark-gap, controlled by a thyratron and an induction coil.

There is a noticeable time-lag between grounding of electrode C and

\* Coined from the initials of the Direction des Etudes et Fabrications d'Armement (DEFA).

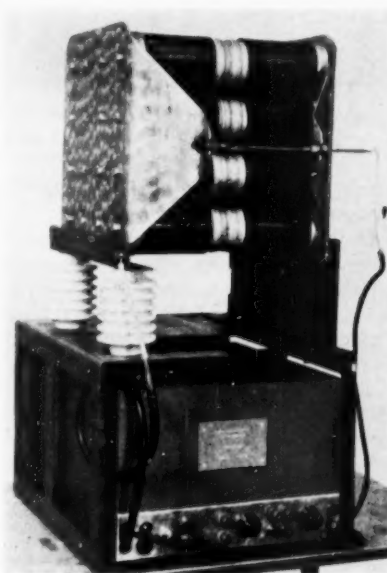
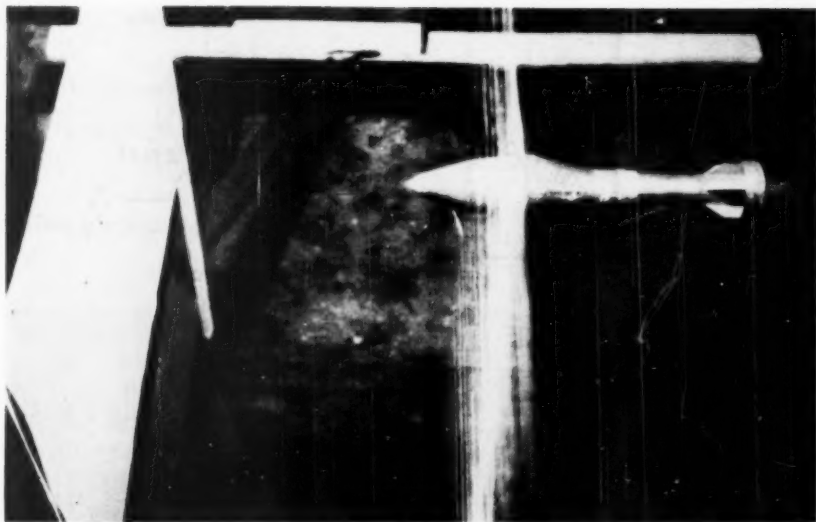


Fig. 9. Defatron spark generator.

breakdown. Under the conditions mentioned above, the time-lag is of the order of  $1 \mu\text{sec}$ , with rather large dispersion. It will be explained later how this time-lag may be used to advantage for the control of a Kerr-cell shutter.

Figure 9 shows the Defatron unit. The removable cabinet placed under the  $0.8 \mu\text{F}$  condenser battery contains the



**Fig. 10. Defatron exposure of 100-mm rocket projectile in flight.**  
Flash duration: 1  $\mu$ sec; distance: 5 m at  $f/3.5$ .

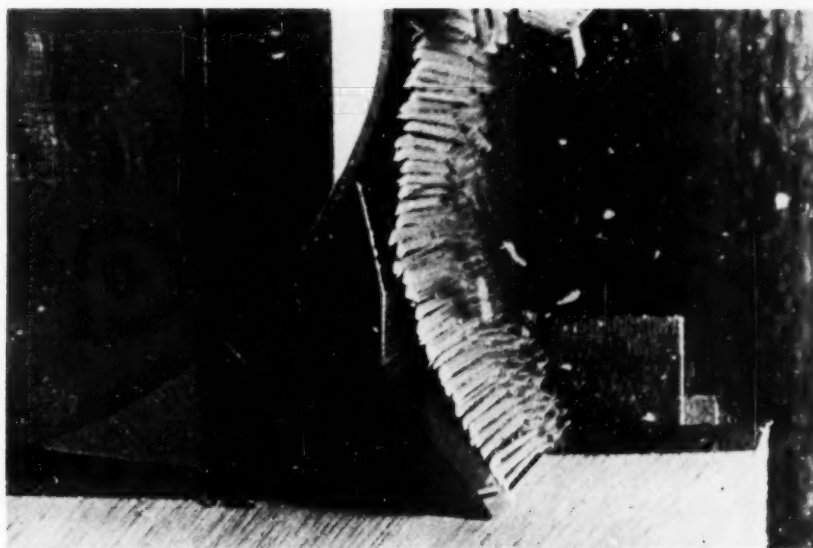
power supply, the high-voltage generator and the triggering device.

In the original Defatron, the insulator tube, made of Pyrex glass, had a very variable life, presumably due to minute defects in the material. Besides, it was impossible to avoid coiling of the spark around the tube, resulting in variations of light output from shot to shot. Recently these two detrimental effects have been obviated by our scientific collaborator P. E. Tawil by substituting a plastic tube for the Pyrex tube. Over the 0.5-mm thick plastic tube is glued a second layer of plastic provided with a slit in which breakdown occurs. A linear spark is thus obtained, resulting in a perfectly repeatable light output. The tube, whose life ranges from about 100 to 300 flashes, may be changed in a matter of seconds.

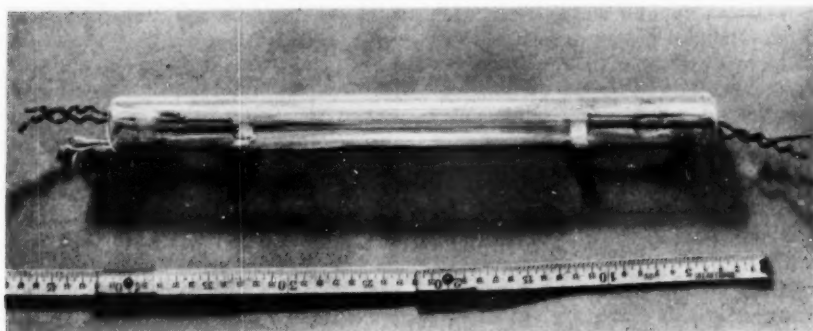
The flash duration is about 1  $\mu$ sec. The light output is adequate to photograph a 125 sq ft surface of medium reflectivity from a distance of more than 20 ft with an  $f$ /number of 3.5. This is illustrated by Fig. 10, which shows a

100-mm rocket projectile, photographed from a distance of 16 ft. It is of interest to mention that we experience no difficulty in using air sparks in bad weather conditions. This is due to the use of a long guided spark and to the large factor of safety of the triggering spark-gap, with the same design as that of Fig. 2. This sort of spark-gap never needs to be adjusted to the atmospheric humidity. A large number of Defatrons have been constructed at an approximate cost of \$1000 each, and thousands of pictures of experimental missiles of all kinds have been taken. Our instrument has also been successfully used for the investigation of more peaceful phenomena, such as the operation of water-atomizing machines and the cutting of tropical wood (Fig. 11). For these and other applications, stereoscopic photographs were made.

If more light is needed and if an increase of the flash duration to a few  $\mu$ sec is not detrimental, the gas-discharge tube in Fig. 12 may be substituted for the Defatron guided spark. It is filled



**Fig. 11. Defatron exposure of chip formation during cutting of test piece of tropical wood with experimental tool.**  
(Courtesy of Centre Technique Forestier Tropical, Vincennes, France.)



**Fig. 12. Argon-hydrogen tube for 200-j discharge.**

with a mixture of argon and 10% hydrogen at atmospheric pressure. Its light output is about four times as high as that of the guided spark in air. The control electrode takes the form of a metal layer outside the glass envelope, which also acts as a reflector.

#### **Simple Electronic Delay Circuit**

In many cases it is necessary to introduce an intentional delay between the timing pulse from the transducer and the flash.

Theoretically, any of the well-known linear delay circuits, such as the cathode-

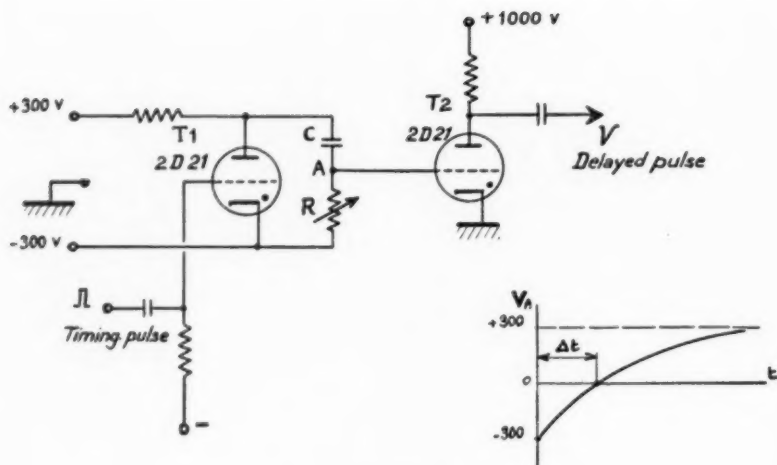


Fig. 13. Simple RC delay circuit.

coupled multivibrator and the phantatron, could have been used. But if the flash is to be delayed with respect to a previous flash — as is the case, for example, in multiple-flash photography — it is extremely difficult to make such vacuum-tube delay circuits insensitive to the high-voltage discharge of the first flash. Our purpose being the development of an all-purpose reliable delay system, we decided to use the very simple RC circuit, the principle of which is shown in Fig. 13.

When the primary pulse fires thyatron T<sub>1</sub>, condenser C, initially charged at 600 v, discharges through resistor R and the plate-cathode space of T<sub>1</sub>. The potential V<sub>A</sub> at point A, initially -300 v, then tends exponentially toward +300 v, with the time-constant RC. Thyatron T<sub>2</sub> fires and thus generates the delayed pulse when this exponential voltage wave goes through its firing voltage which, for the sake of clarity, has been assumed negligible. The values of R and C should be so chosen that the internal resistance of thyatron T<sub>1</sub>, while conducting, is negligible with respect to R. If the ratio of maximum to

minimum delay is kept at a reasonable value, say 20, the accuracy of this circuit is of the order of 0.5%, while its short-term reproducibility is only a small fraction of 1%. This kind of performance is adequate for most practical applications.

#### Kerr-Cell Shutter

The principle of the Kerr-cell high-speed shutter is too well known to be repeated here. Suffice it to say that certain fluids, such as nitrobenzene, become birefractive under the influence of an electrostatic field. A Kerr cell thus consists of a vessel filled with nitrobenzene and provided with a system of electrodes capable of creating in the liquid a uniform electrostatic field. If this system is placed between two crossed polaroids along the path of a quasi-parallel beam of light, and no voltage is applied across the electrodes, it lets through only a very small residual fraction of the incident light. It becomes transparent if a suitable voltage is applied across the electrodes. A high-speed shutter is obtained by combining a Kerr cell with a suitable control circuit generating at the

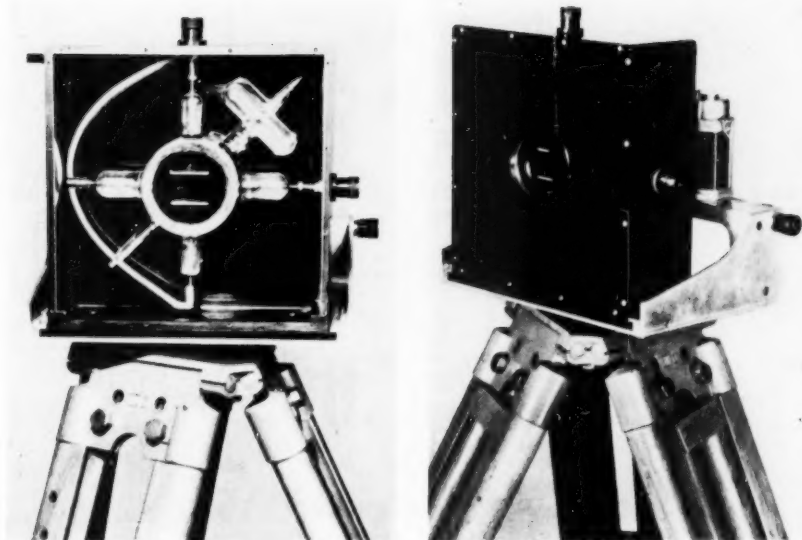


Fig. 14. Kerr-cell shutter; left, with cover removed; right, ready for use with 35mm Foca camera.

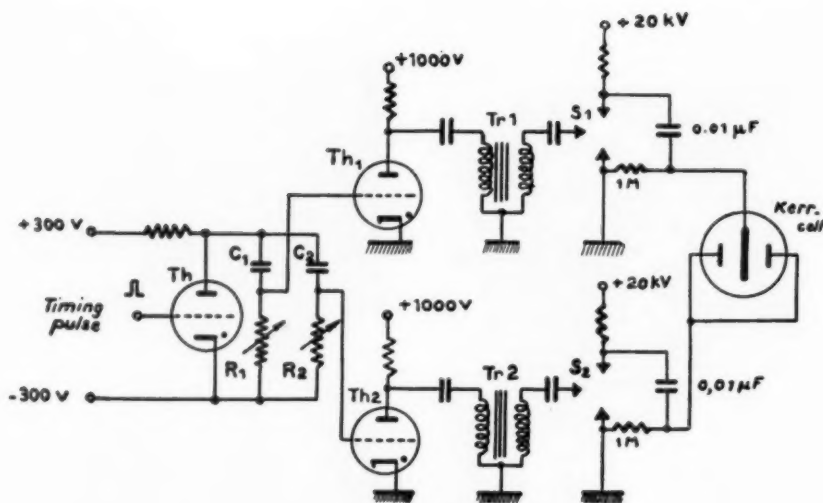
proper moment a rectangular pulse of the required amplitude and duration. The chief disadvantage of this system is its poor transmission, less than 10%.

Our standard Kerr cell was developed by our scientific collaborator P. E. Tawil, well-known for his piezo-optical Kerr-cell chronograph.<sup>6,7</sup> It is made of welded glass and has three electrodes (Fig. 14). It is fully open for a voltage of 22 kv. Its useful cross section is  $15 \times 15$  mm and so does not stop down the standard SOM objective (50-mm focal length,  $f/3.5$ ) provided with the 35mm Foca camera.

Our pulse generator results from the combination of two RC delay networks (Fig. 15). It thus opens the Kerr cell during an adjustable time-interval, with an adjustable time-lag with respect to a timing pulse. In the steady state, there is no voltage across the cell, its two poles being grounded. The rectangular 22-kv pulse across the cell is pro-

duced by triggering the spark-gaps  $S_1$  and  $S_2$  in succession, by means of thyratrons  $Th_1$  and  $Th_2$ , and pulse transformers  $Tr_1$  and  $Tr_2$ . The high time-constant of both discharge circuits gives a perfectly rectangular pulse. The two thyratrons are fired by discharging condensers  $C_1$  and  $C_2$  through resistors  $R_1$  and  $R_2$  and the master thyatron  $Th$ , triggered by the timing pulse. The two delay circuits can be set for any desired maximum delay; in a typical case, the maximum delay is 7  $\mu\text{sec}$  and the pulse duration defined with an accuracy of 0.1  $\mu\text{sec}$ . Figure 16 shows the detonation of a small explosive charge, photographed with an exposure time of 0.5  $\mu\text{sec}$ . For very short exposure times, of the order of 0.1  $\mu\text{sec}$ , spark gap  $S_2$  is simply triggered by connecting its control electrode to the anode of  $S_1$  by a length of coaxial cable.

If the subject is not self-luminous and must therefore be illuminated, a very



All thyatrons 2D21

Fig. 15. Circuit for the generation of rectangular high-voltage pulses.

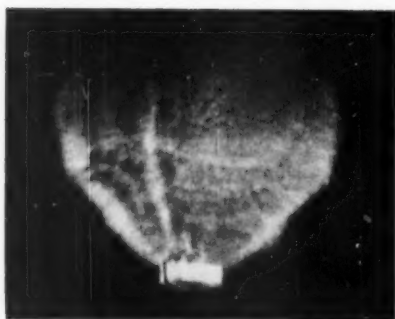


Fig. 16. Detonation of a small explosive charge, photographed with the Kerr-cell shutter shown in Fig. 15, with an exposure time of  $0.5 \mu\text{sec}$ .

simple method can be used to synchronize the Kerr-cell shutter with a guided spark or similar source and to open the shutter during the whole duration of the flash (Fig. 17). This circuit puts to advantage the time-lag of a subsidiary guided spark  $G$ . The Kerr cell is connected between the control electrode of

the main guided spark  $G_1$  and the anode of the subsidiary guided spark  $G_2$ . The shutter opens up when the control electrode of  $G_1$  is grounded, i.e., before the flash, and closes down when  $G_2$  breaks down after the most luminous portion of  $G_1$ 's flash. The photographs in Fig. 18, which shows a 20-mm shell in flight, were obtained under these conditions; triggering was achieved by short-circuiting two aluminum sheets separated by a sheet of paper.

#### Four-Spark Generator for Shadowgraphic Exposures

It is clear that the basic spark and delay circuits discussed above can be combined in many ways to obtain high-definition multiple exposures at rates up to several million frames/sec. Higher rates are seldom if ever justified in practice. Among these many possibilities, we have chosen to describe here two instruments which we have already manufactured for several outside users: a 4-spark generator for shadowgraphic

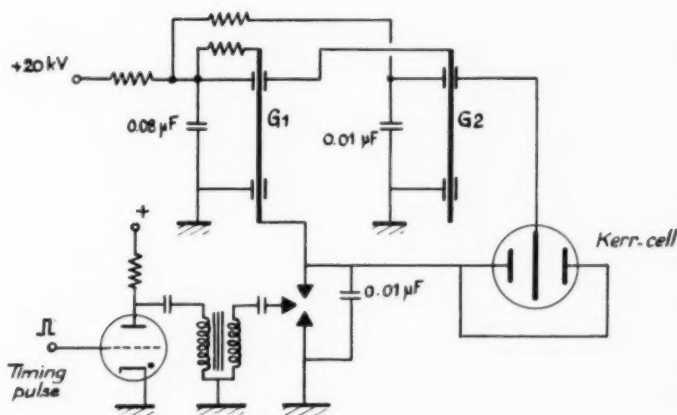


Fig. 17. Circuit for synchronization of Kerr-cell shutter with Defatron guided-spark generator.

exposures and a 30-flash instrument for silhouette and schlieren exposures.

The purpose of the 4-spark generator is to produce 4 sparks in succession in one and the same pinpoint spark-gap. This is possible even at very high rates if the 4 discharge circuits are completely separate except for the common pinpoint spark-gap (Fig. 19). At rates above 10 kc the first spark is more luminous than the succeeding three, which break down in an already ionized channel. This may be counteracted by the selection of a smaller value for the first spark condenser. The 4 triggering spark-gaps are controlled in a manner similar to that of Fig. 15, although it would perhaps be better to use a method similar to that used for the 30-flash instrument (see below). The maximum rate is about 100 kc, if automobile coils are used, and 200 kc with pulse transformers. Figure 20 shows an instrument equipped with 4 auto coils. A typical quadruple exposure is shown in Fig. 21.

When a small number of photographs is sufficient to analyze the observed phenomenon, this instrument has two significant advantages: (1) no optical

system is needed; and (2) geometrical evaluation of the exposures is very simple, as they are free of parallax with respect to one another. The 4 shadows are merely superimposed on one and the same photographic plate or paper. Figures 4 and 21 show that a reasonably good contrast can be obtained with 4 or 5 superimposed pictures. In some cases, 8 exposures may be obtained by cascading two instruments.

#### Electronic Million-Frames/Sec Camera

This flash generator was especially designed for use with the Cranz-Schardin optical setup, which makes it possible to obtain several dozen separate high-definition transmission images with no limitation in rate.<sup>8,9</sup> The principle is illustrated in Fig. 22 for 4 pictures. The 4 light sources  $S_1$  to  $S_4$  are conjugate of the 4 objectives  $O_1$  to  $O_4$  with respect to the field lens  $F$ . The photographic plate  $P$  is in turn conjugate of the object  $A$  with respect to the objectives  $O$ . Therefore, when each light source is flashed, its rays go through the corresponding objective only, and an image is formed on the photographic plate. Control, thus, simply consists in

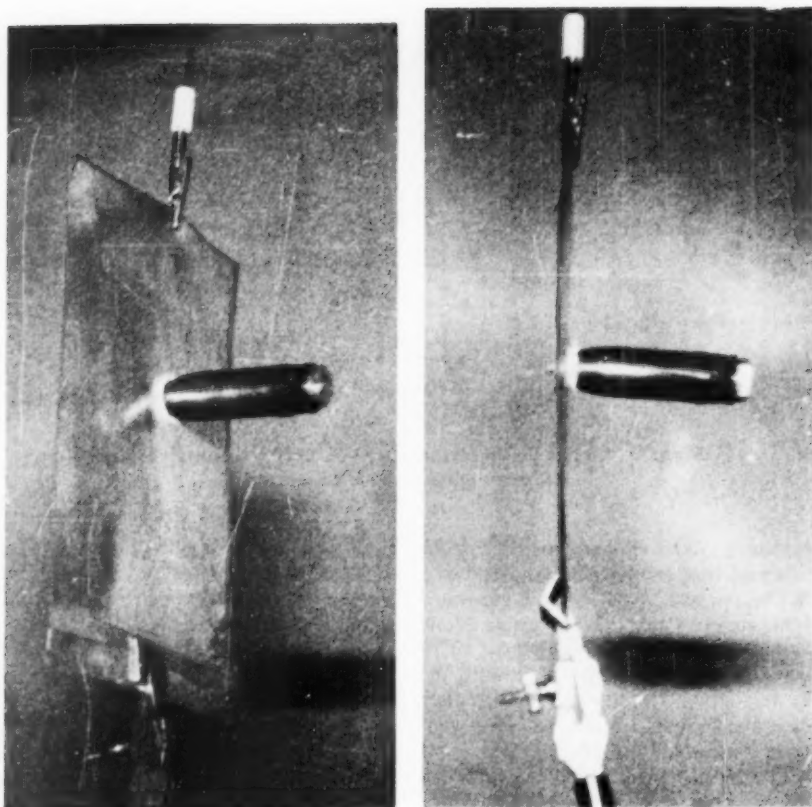


Fig. 18. 20-mm shell photographed with Defatron and Kerr-cell shutter; triggering achieved by short-circuiting two metal sheets separated by a sheet of paper.

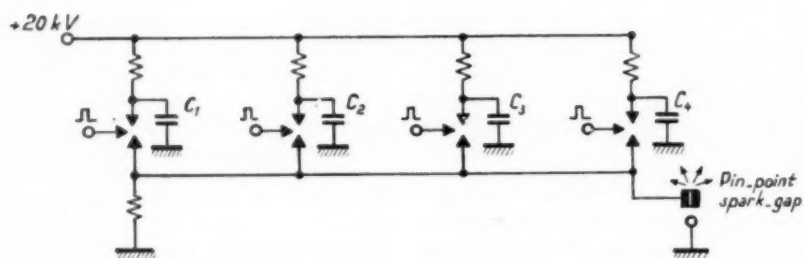


Fig. 19. High-voltage circuit of 4-spark generator.

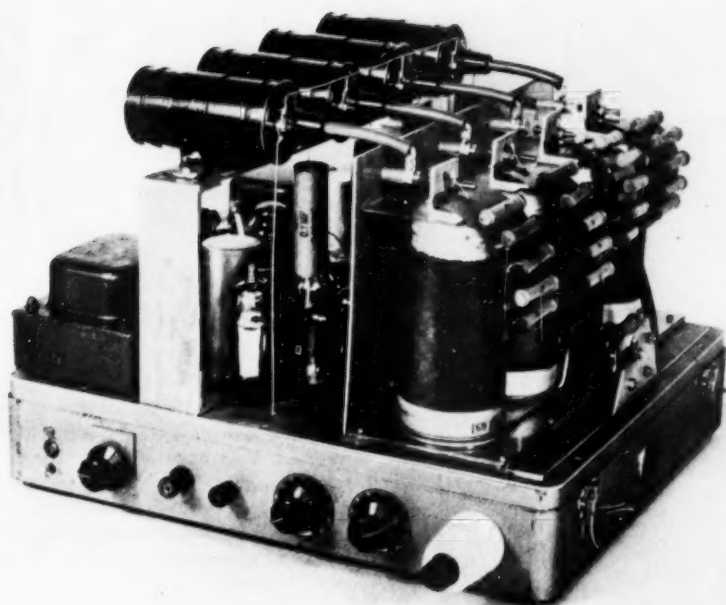


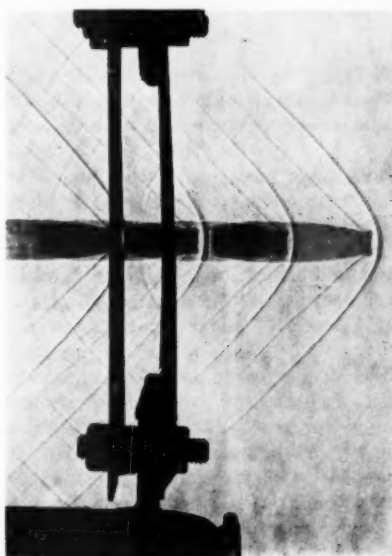
Fig. 20. Four-spark generator with cover removed.

Fig. 21. Four phases of the motion of a rifle bullet photographed with the instrument shown in Fig. 20.

triggering the light sources in succession at the desired rate.

This optical setup yields silhouettes, although the objective mounts act as schlieren diaphragms and make visible large index variations produced, for example, by shock waves. If actual schlieren photographs are required, a good-quality field optic should be used, the light sources should have a well-defined geometrical form — linear or circular — and proper diaphragms should be placed in front of the objectives.

The LCA electronic million-frames/sec camera, using this principle, was designed to yield 30 frames at rates from 50 kc up to 1 mc, although a different



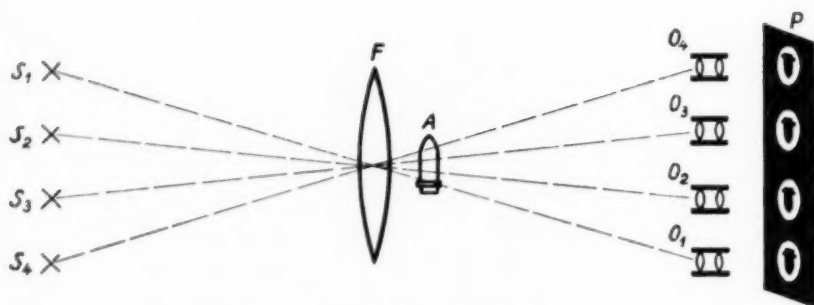


Fig. 22. Cranz-Schardin optical setup.

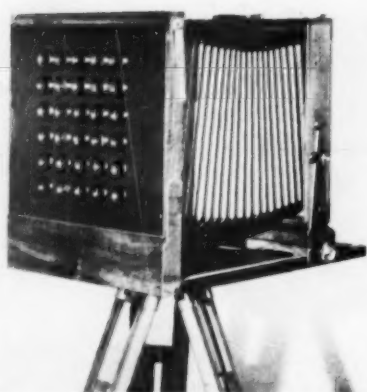


Fig. 23. Thirty-objective camera for use with the Cranz-Schardin optical setup.

rate range can easily be obtained by changing a few condensers and resistors. The light sources are krypton tubes of the type shown in Fig. 7C. They may be oriented either horizontally or vertically by rotating the plastic tube mount (Figure 26). The 30 pictures are formed on a standard  $24 \times 30$  cm plate. The 30 objectives are merely achromatic lenses with a focal length of 345 mm and an  $f$ /number of 1/14. The 30-objectives camera is shown in Fig. 23. Adjustable schlieren knife-edges may be placed in front of the objectives.

For silhouette photography, the optical system consists of an ordinary condenser

with a diameter of 40 cm and a focal length of 1.8 m. The distance between the light sources and the objectives is thus 7.2 m. For schlieren work, we use a single concave mirror accurate to one wavelength, with a diameter of 50 cm and a focal length of 3 m, but it should be noticed that, with the V setup using a mirror, the field common to all frames is much smaller than the mirror diameter (Fig. 24). This is due to the dimensions of the source and objective assemblies, which introduce a noticeable parallax, and to the fact that the subject should be placed sufficiently ahead of the mirror to be crossed only once by the light rays. These facts make the use of the Z setup with two mirrors almost impossible for multiple-frame schlieren photography.

As early as 1929, Cranz and Schardin used this optical setup, with spark-gaps instead of gas tubes, in conjunction with a purely electrical method of control. The Cranz-Schardin circuit essentially consists of a number of Mach LC delay networks connected in cascade. Up to 24 frames at rates ranging from a few thousands to one million frames/sec were successfully obtained. This instrument was further improved by Vollrath at the Ballistics Research Laboratory at St. Louis, France, where several units are in current use. The chief disadvantage of such purely electrical devices is their bulkiness.

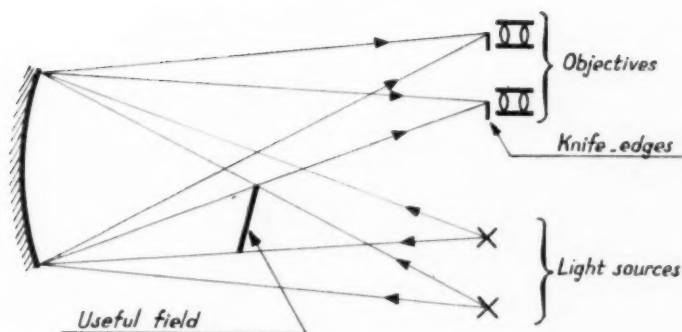


Fig. 24. V-setup for schlieren photography.

Their frequency range is covered by having one set of inductances for each required rate. These inductances are far from small and their storage is liable to become quite a problem. This difficulty is, of course, eliminated by the use of electronic circuits with radio potentiometers as variable elements. The first instrument of this type was developed during the last war by C. A. Adams at the British Armament Research Department.

There are two fundamental methods of triggering the elementary discharge circuits in succession at the desired rate:

1. By means of an electrical pulse delayed by an adjustable amount with respect to a master pulse produced by the phenomenon being studied. This system is effectively adopted in the Adams instrument.

2. By an electrical pulse delayed with respect to the previous discharge. This is the method used in the Cranz-Schardin circuit and in our own instrument.

Both methods have their advantages and drawbacks. If a large frequency range is to be covered, the first method is liable to introduce overlaps and interchange of frames at the higher frequencies, because of the unavoidable dispersion of the delay circuits. On the other hand, the minimum feasible delay sets a higher limit to the frequency

obtainable with the second method. This limit may be lower than that obtainable with the first method, which depends on the accuracy of the delay circuits.

Therefore, we would recommend the use of the first method for a relatively narrow frequency range up to a few megacycles, and that of the second method for a wider frequency range — say 20 to 1 — up to the maximum frequency set by the minimum delay.

In the case of our circuit, which involves two 2D21 thyratrons per stage, the minimum delay is of the order of  $1 \mu\text{sec}$ , so that the maximum frequency is 1 mc. The delay circuits are set for a range of 20 to 1.

Each of the 30 discharge circuits is triggered by the previous one, except for the first one, which is triggered by a suitable transducer actuated by the observed phenomenon. Use is made of the discharge and delay circuits described above. Figure 25 shows one of the discharge circuits and its coupling with the previous one. The timing pulse is derived from the previous discharge circuit by transformer action, by means of a few turns of wire wound round the high-voltage condenser lead. From then on, condenser C discharges exponentially through resistor R and thyratron  $\text{Th}_1$ . Thyratron  $\text{Th}_2$  eventually

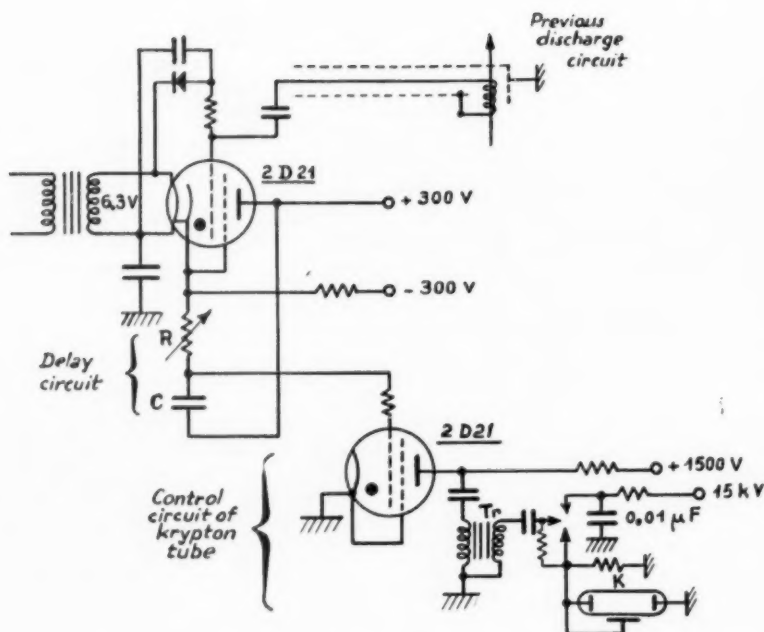


Fig. 25. Circuit diagram of one stage of LCA 30-flash generator.

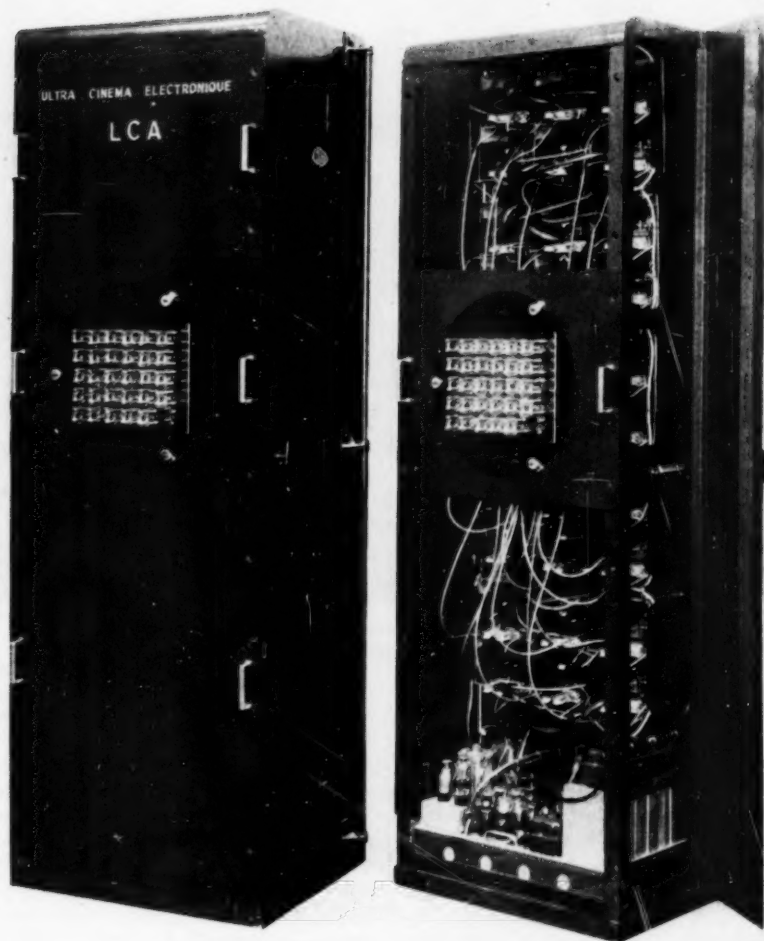
fires and triggers the krypton-tube discharge circuit. In this case, the high voltage is only 15 kv. As the krypton tube breakdown voltage is only 2.5 kv it is mounted in series with an auxiliary spark-gap S, which is triggered in the usual manner by means of a control electrode and a pulse transformer. Firing of the tube is assisted by a few turns of wire wound round the glass envelope.

Figure 26 shows this 30-flash generator. On the front can be seen the orientable plastic holder for the 30 krypton tubes. The power supply is housed at the bottom of the cabinet. Each of the 30 discharge and delay circuits may be quickly removed and replaced individually; they are all interchangeable. But the actual constructional unit of the instrument is a group of six such circuits, so that instruments may be delivered with any number of flashes equal to a

multiple of six, up to 30. Two 30-flash instruments have been made to date at an approximate cost of \$6000 each, one for our own laboratory, the other for another DEFA establishment. A 24-flash unit has just been delivered to the Swedish armament research organization. A slightly different 18-flash unit was delivered last year to the research laboratories of the French Coal Industry Organization.

Figure 27 shows a typical schlieren exposure produced by the 18-picture instrument.

This method of analysis of high-speed phenomena has the advantage of yielding high-definition images, irrespective of the picture rate, as there is no moving part in the optical system. The small number of pictures is largely compensated for by the fact that it is possible to start the sequence precisely at the beginning of the interesting phase of the

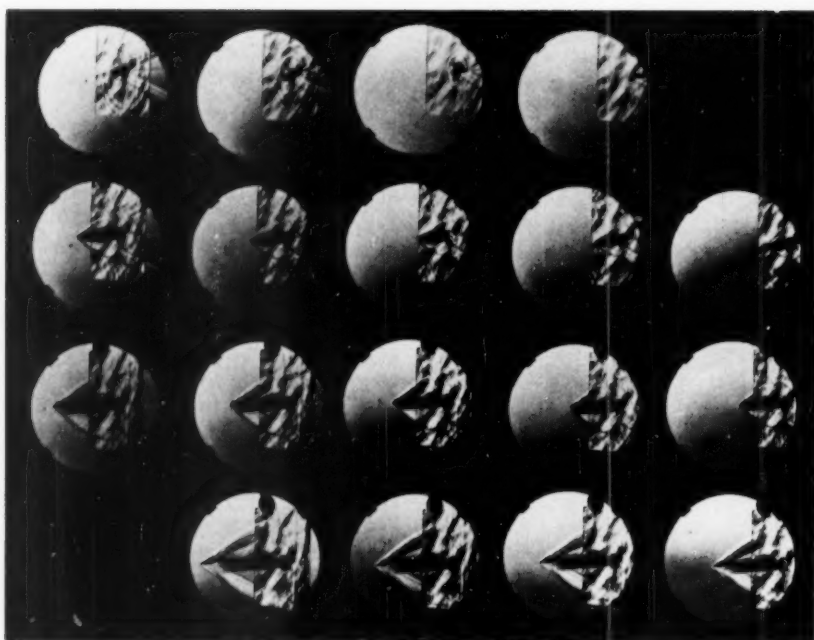


**Fig. 26.** LCA 30-flash generator; left, exterior view, right, with covers removed.

phenomenon. Also, it is possible with as few as 20 or 30 pictures to print a projectable motion picture that actually gives the illusion of motion.

Although the calibration accuracy of the delay networks is often adequate, it is sometimes necessary to determine the time intervals between flashes with a

separate chronograph. For this purpose our colleague Paul Devaux has developed an experimental cathode-ray tube chronograph using a Philips television projection tube and a linear zig-zag sweep with a frequency of 500 kc. The trace is calibrated by means of a superimposed 2 mc/sec sinusoid. The



**Fig. 27. Eighteen frames taken at a rate of approximately 100,000 frames/sec and showing penetration of a rifle bullet through a glass plate.**

flashes are converted into electrical pulses by means of a photomultiplier and a wide-band amplifier and appear on the oscillogram as interruptions of the trace. The instrument has an accuracy of  $10^{-8}$  sec.

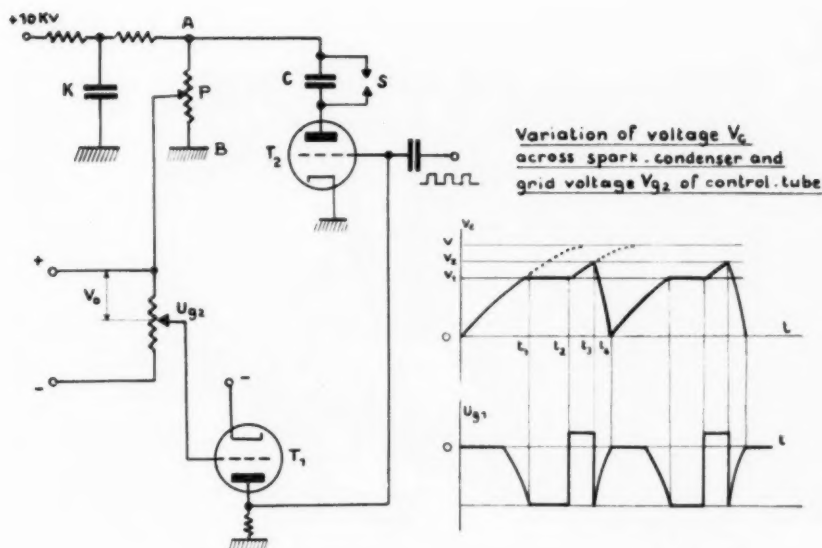
#### **Electronic Spark Generator for Silhouette Cinematography**

Although it stands in a class apart from those discussed above, this instrument is described here because it shows how electronic methods of control make it possible to modify the properties of a spark-gap.

The older Schatte<sup>10,11</sup> and Toepler methods of generating spark sequences at high frequencies in a single spark-gap essentially consist in the gradual discharge of a large storage condenser into a small spark condenser by means, respectively, of a simple RC or LC

relaxation circuit. Such purely electrical control methods have two major disadvantages. First, the spark frequency is not constant throughout the discharge, but decreases in the Schatte method and goes through a maximum in the Toepler method. Also, the electric current through the spark-gap is never zero even during a portion of the recurrence period. This results in bad de-ionization conditions and the necessity of a powerful air blast for frequencies above 20 kc. These two difficulties are obviated in the electronic spark generator, designed by Paul Devaux, by controlling the charging current through the use of a vacuum tube.

The circuit diagram is shown in Fig. 28. The energy of the whole spark sequence is stored in the  $1 \mu\text{f}$  storage condenser K, which is discharged in steps into the  $0.001 \mu\text{f}$  spark condenser



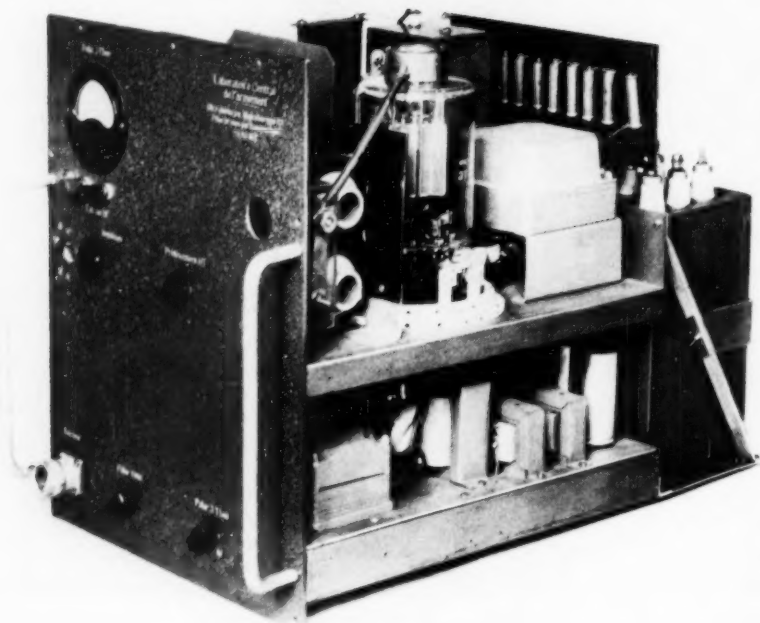
**Fig. 28. Circuit diagram of spark generator for cinematography at 50,000 frames/sec.**

C across the spark-gap S. The charging current is controlled by transmitter tube  $T_1$  in such a manner that it is interrupted during the time interval  $t_1/t_2$  preceding the spark breakdown, during which the voltage across S remains constant and equal to  $V_1$ . Thus the spark-gap breakdown voltage  $V_s$  should be between  $V_1$  and the voltage  $V$  across  $K_s$  initially 10 kv. Tube  $T_1$  is itself controlled by receiver tube  $T_2$ , whose grid voltage is derived from the spark condenser voltage by means of a potentiometer and a bias battery. Just after the spark breakdown,  $T_1$  is conducting while  $T_2$  is cut off. The spark condenser voltage and, hence, the grid voltage of  $T_2$ , then increase exponentially. When  $T_2$  starts drawing plate current, the grid voltage of  $T_1$  begins to decrease, until time  $t_1$  when  $T_1$  is completely cut off and the charging current is interrupted. From then on, the voltage across C remains constant until a rectangular pulse is applied to the grid of  $T_1$  and

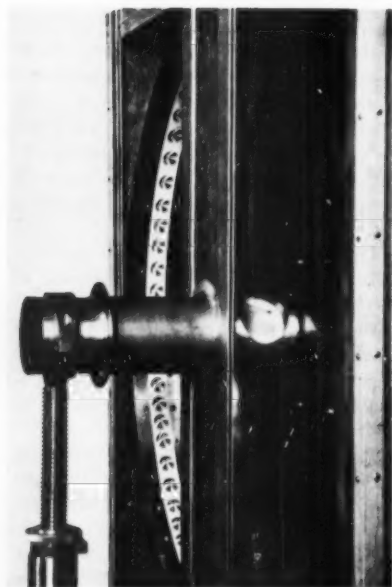
time  $t_2$ . Charging of C is then resumed until time  $t_3$ , when breakdown occurs. The voltage across C is again at zero at time  $t_4$ , when the circuit is ready to repeat the same cycle of operation. The periodic pulses applied to the grid of  $T_1$  are produced by a variable-frequency pulse generator exterior to the spark generator proper. Figure 29 shows the spark generator with the cover removed.

The above circuit makes it possible to reach a rate of 50,000 sparks/sec in air without any air-blast.

The images are recorded by means of the rotating-mirror camera shown in Fig. 30, with the optical setup of Fig. 31. The fixed rim of this camera holds about 2.5 m of standard 35mm film. At the maximum mirror speed of 20,000 rpm, about 200 circular images 10 mm in diameter may be recorded at the rate of 50,000 frames/sec. Figure 32 shows a portion of a typical record of the impact failure of a standard European notched



**Fig. 29. Spark generator with cover removed.**



**Fig. 30. Close-up of the rotating-mirror camera.**

bar at the rate of 30,000 frames/sec. It may be seen that, owing to mirror rotation, the image rotates in its plane at the rate of one complete revolution for each mirror revolution.

It is clear that, in order to avoid superimposition of the images on the film, the spark sequence must not last longer than one mirror revolution. This is achieved by means of an electronic switch and a delay circuit, as shown in Fig. 33. The timing pulse derived from the observed phenomenon via a suitable transducer closes the electronic switch and simultaneously triggers a delay circuit set to a time interval equal to one mirror revolution. The electronic

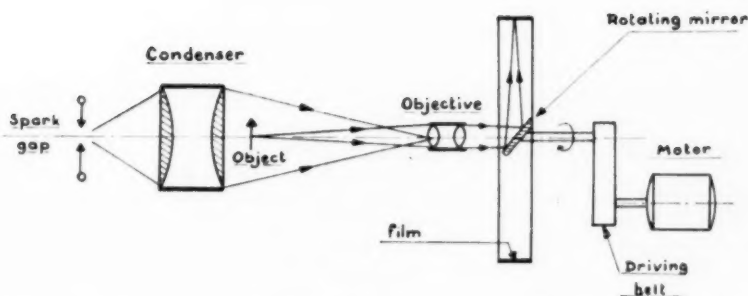
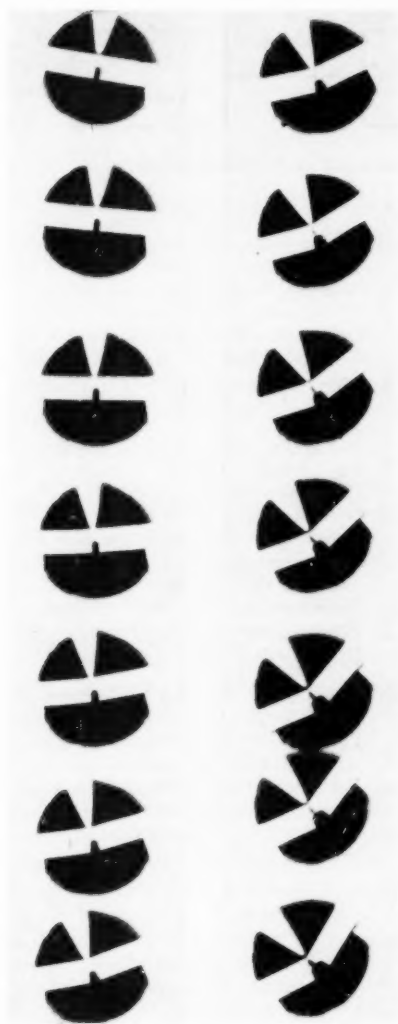


Fig. 31. Optical setup for cinematography at 50,000 frames/sec.

Fig. 32. Failure of notched bar, recorded at the rate of 30,000 frames/sec.



switch is reset by the delayed pulse. The delay circuit is of the type described above.

#### Conclusion

The methods described in this paper are essentially the modern electronic counterparts of very old electrical methods of high-speed photography and cinematography. The introduction of electronic control devices has made the instruments more accurate, more reliable, more flexible, and therefore easier to handle. No special skill is now required to photograph a projectile at a point of its trajectory defined to an accuracy of 1 mm or less or to analyze its motion at a rate of 1,000,000 frames/sec.

It would be a fruitless task to attempt to evaluate these methods against mechanical methods of high-speed motion picture photography. Electrical and mechanical methods should rather be considered as complementary. In some cases, the best solution lies in a combination of each. The methods described above are particularly well suited to the investigation of fast transient phenomena of the nonluminous type, such as are often encountered in ballistics. The choice of a method suitable for a particular application is often difficult; except

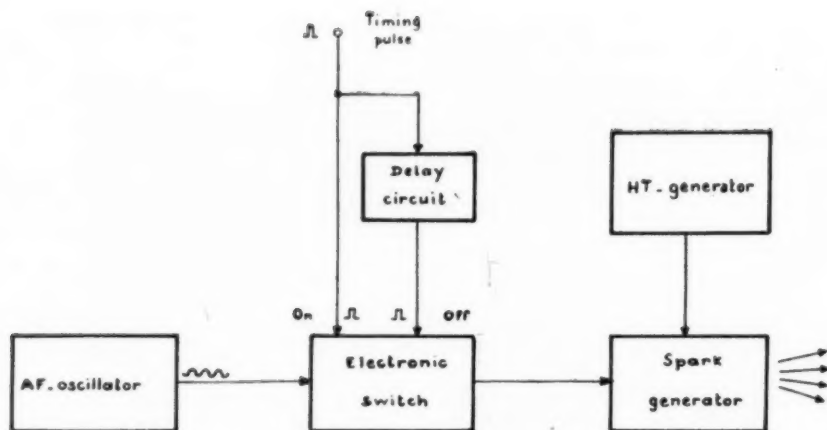


Fig. 33. Block diagram of spark generator and electronic switch.

for very obvious cases, consultation of an expert with wide experience in the field cannot be too strongly recommended.

#### Acknowledgments

Our thanks are due to our colleague Paul Devaux, whose experimental skill and sound engineering played a major part in the successful design of the instruments described.

We finally wish to extend our thanks to the Direction des Études et Fabrications de l'Armement, Paris, France, by whose permission this paper is presented.

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## Proposed Revisions, PH22.2 and PH22.3 35mm Film Usage in Camera and Projector

TWO REVISED American Standards are published on the following pages for 3-month trial and criticism. All comments should be sent to Henry Kogel, Staff Engineer, prior to August 15, 1953. If no adverse comments are received, the two proposals will then be submitted to ASA Sectional Committee PH22 for further processing as American Standards.

The Sound Committee's proposed revisions are primarily a simplification of the titles and an addition of a tolerance to the specification of distance between sound and picture.—H.K.

## Standards PH22.39, - .53, - .86 and - .87 35mm Screen Brightness; Resolving Power of 16mm Projector Lenses; Dimensions for Magnetic Sound Tracks

THE FOLLOWING proposed standards were approved as American Standards on April 16, 1953, and are published on the following pages as approved:

PH22.39-1953 (Revision of Z22.39-1944), Screen Brightness for 35mm Motion Pictures.

PH22.53-1953 (Revision of Z22.53-1946), Method of Determining Resolving Power of 16mm Motion-Picture Projector Lenses.

PH22.86-1953, Dimensions for 200-Mil Magnetic Sound Tracks on 35mm and 17½mm Motion-Picture Film.

PH22.87-1953, Dimensions for 100-Mil Magnetic Coating on Single-Perforated 16mm Motion-Picture Film.

PH22.39 was published for comment in the May 1952 *Journal*. Addition of the note on outdoor theaters was and is the only change in the 1944 standard.

The revisions of PH22.53 were not of major proportions and so were not published. Slight changes were made in paragraphs 2.2 and 3.1 and a new section, 3.1.1, was added to amplify a provision previously stated in paragraph 3.1.

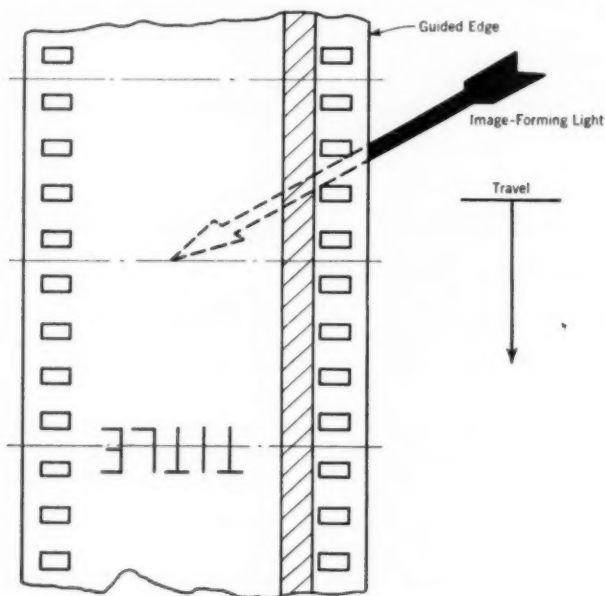
The two new proposals, PH22.86 and PH22.87 were published for trial and comment in the July 1951 *Journal*. One serious objection was made to the 35mm-17½mm proposal which formed the basis of a paper which was delivered before the 70th Convention at Hollywood in October 1951 and published in the February 1952 *Journal*. After full discussions, the objection (an alternate proposal for four tracks instead of three) was voted down. There was also one objection to the 16mm proposal based on a fear that the magnetic coating might produce excessive wear in the guide rails. This was viewed, however, as a problem in design and manufacture, not standardization, and the objection was withdrawn. Editorial changes were made in both standards and therefore the approved standards published here differ slightly from the drafts as first published.—H.K.

PROPOSED AMERICAN STANDARD  
35mm Sound Motion-Picture Film—  
Usage in Camera

(Second Draft)

PH22.2

Revision of Z22.2-1945



Drawing shows film as seen from inside the camera  
looking toward the camera lens.

**1. Position of the Emulsion**

**1.1** Except for special processes, the emulsion shall be toward the camera lens.

**2. Rate of Exposure**

**2.1** The rate of exposure shall be 24 frames per second.

**3. Relationship Between Sound and Picture**

**3.1** The apparatus and film shall be so arranged that the sound is placed on the film 20 frames,  $\pm \frac{1}{2}$  frame, ahead of the horizontal centerline through the corresponding picture. Thus, a given point on the film shall pass the sound head after it has passed the picture aperture.

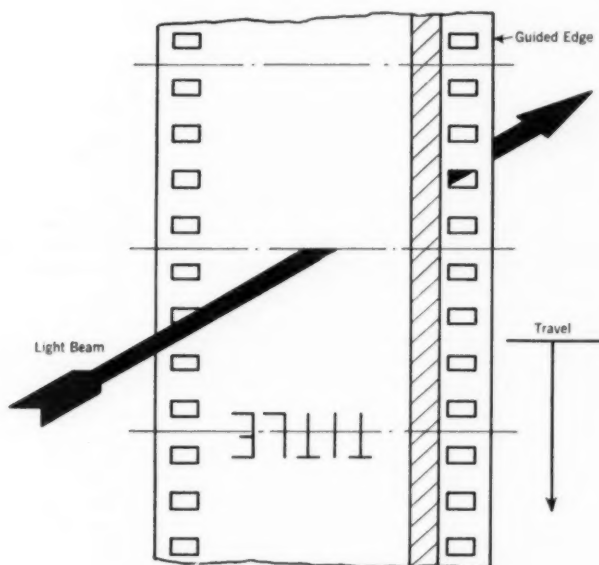
NOT APPROVED

PROPOSED AMERICAN STANDARD  
35mm Sound Motion-Picture Film—  
Usage in Projector

(Second Draft)

PH22.3

Revision of 222.3-1946



Drawing shows film as seen from the light-source in the projector.

**1. Position of the Emulsion**

1.1 Except for special processes, the emulsion shall be toward the light-source of the projector.

**2. Rate of Projection**

2.1 The rate of projection shall be 24 frames per second.

**3. Relationship Between Sound and Picture**

3.1 The apparatus and the film shall be so arranged that when the film is threaded normally, the sound track is scanned for reproduction at a point 20 frames,  $\pm \frac{1}{2}$  frame, ahead of the centerline through the picture being projected. Thus, a given point on the film shall pass the sound head after it has passed the picture aperture.

NOT APPROVED

AMERICAN STANDARD

# Screen Brightness for 35mm Motion Pictures

ASA  
Reg. U. S. Pat. Off.  
**PH22.39-1953**  
Revision of Z22.39-1944  
\*UDC: 778.55

## 1. Screen Brightness

**1.1** The brightness at the center of a screen for viewing 35mm motion pictures in indoor theaters shall be  $10^{+1}_{-1}$  footlambert when the projector is running with no film in the gate.

**Note:** Outdoor theaters have been excluded from this standard because of their inability to meet it. It is recommended that outdoor theaters approach the indoor standards as closely as possible in view of the fact that the same release prints are generally used for both types of theaters.

Approved April 16, 1953, by the American Standards Association, Incorporated  
Sponsor: Society of Motion Picture and Television Engineers

\*Universal Decimal Classification

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70 East Forty-fifth Street, New York 17, N. Y.

Printed in U.S.A.  
ASA14M603

Price, 25 Cents

AMERICAN STANDARD  
Method of Determining  
Resolving Power of 16mm Motion-Picture  
Projector Lenses

ASA  
Reg. U. S. Pat. Off.

PH22.53-1953

Revision of Z22.53-1948

\*UDC 778.55

Page 1 of 2 pages

### 1. Scope

**1.1** This standard describes a method of determining the resolving power of projection lenses used in 16mm motion-picture projectors. The resolving power shall be measured in lines per millimeter.

### 2. Test Method

**2.1** The lens to be tested shall be mounted in a special test projector. A glass plate test object, carrying patterns of lines, shall be then projected upon a white matte grainless screen located at such a distance from the projector that the projected image of the border of the test object measures  $30 \times 40$  inches. The resolving power of the lens is the largest number of lines per millimeter in the test object pattern that an observer standing close to the screen sees definitely resolved in both the radial and tangential directions. Lines shall not be regarded as definitely resolved unless the number of lines in the image is the same as the number of lines in the test object.

**2.1.1** The patterns of lines shall consist of parallel black lines  $2.5/\times$  mm long and  $0.5/\times$  mm wide between the parallel lines, where  $\times$  equals the number of lines per millimeter.

**2.2** Care shall be taken to insure that the screen is perpendicular to the projection axis and that the lens is focused to give the maximum visual contrast in the fine detail of the central image.

### 3. Test Projector

**3.1** The projector design shall be such that the glass plate test object is held in proper relation to the lens axis. It shall not heat the test plate to a temperature which may cause the plate to be fractured or otherwise damaged. The emulsion side of the test plate shall be toward the projection lens.

**3.1.1** The cone of light supplied by the projector shall completely fill the unvignetted aperture of the test lens for all points in the field. This may be verified by lowering the lamp voltage and looking back into the projection lens through holes in the projection screen situated at the stations A, B, C, etc. It can then be easily seen whether the lens aperture is properly filled with light.

### 4. Test Object

**4.1** The glass photographic plate used for making the test object and the lens used in making the reduction of the master test chart shall have sufficiently high resolving power to insure clear definition of all lines in the patterns on the test object.

**4.2** The photographic reduction of the master test chart shall be such that the test object border has a height of 7.21 mm (0.284 inch) and a width of 9.65 mm (0.380 inch) with a radius of 0.5 mm (0.02 inch) in the corners, and such that the sets of lines in the reduced image are spaced 20, 30, 40, 50, 60, 80, and 90 lines per millimeter.

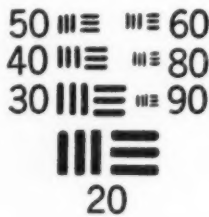
Approved April 16, 1953, by the American Standards Association, Incorporated  
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Price, 25 Cents

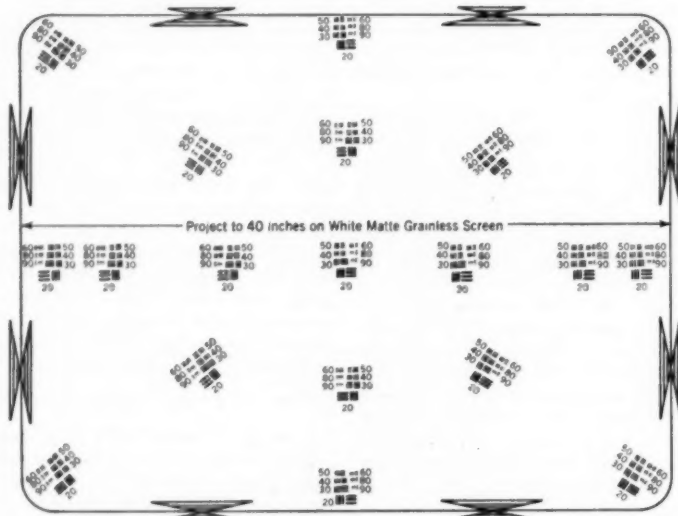


**Fig. 1. Resolution Test Patterns**  
( $\times$  100 Diameters).

**4.3** The patterns on the test object shall be in accordance with Fig. 1.

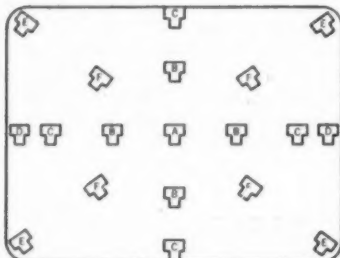
**4.4** The position of the test patterns on the test object shall be in accordance with Fig. 2.

**4.5** Identification of the positions of the test patterns on the test object shall be in accordance with Fig. 3.



**Fig. 2. Resolving Power Test Object** ( $\times$  Approximately 15 Diameters).

**Note:** The triangular edge patterns are to facilitate alignment of test plates in the projector.



**Fig. 3. Identification of Test Patterns in Frame Area.**

**Note:** When not using a 2-inch focal length lens, B corresponds to 2 degrees from the axis, C corresponds to 4 degrees from the axis, D corresponds to 5 degrees from the axis, E corresponds to 6 degrees from the axis, and F corresponds to 3 degrees from the axis.

**Note:** Glass test plates in accordance with this standard are available from the Society of Motion Picture and Television Engineers, 40 West 40th Street, New York 18, N.Y.

PH22.53-1953

**AMERICAN STANDARD**  
**Dimensions for**  
**200-Mil Magnetic Sound Tracks**  
**on 35mm and 17½mm Motion-Picture Film**

**ASA**  
 Reg. U. S. Pat. Off.  
**PH22.86-1953**

\*UDC 778.554.4

Page 1 of 2 pages

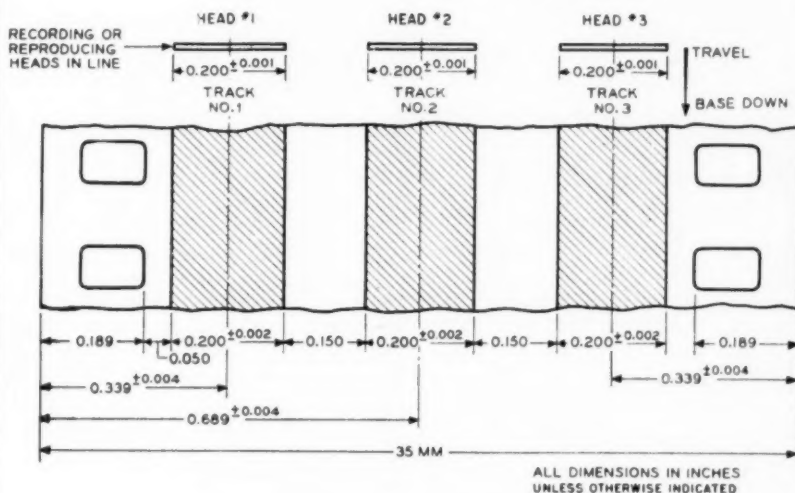
**1. Scope**

**1.1** This standard pertains to magnetic sound records, both single and multiple tracks, on 35mm perforated film, and single tracks on 17½mm perforated film.

**2. Film Base**

**2.1** The film base shall be of the low-shrinkage safety type.

**2.2** With the direction of travel as shown in Fig. 1, the magnetic material is coated on the upper side of the film base.



**Figure 1.**

**3. Dimensions**

**3.1** All dimensions given are relative to unshrunk film.

**3.2** Cutting and perforating dimensions and tolerances are identical to those given in the

American Standard Cutting and Perforating Dimensions for 35mm Motion-Picture Positive Raw Stock, Z22.36-1947, or any subsequent revision thereof approved by the American Standards Association, Incorporated.

Approved April 16, 1953, by the American Standards Association, Incorporated  
 Sponsor: Society of Motion Picture and Television Engineers

\*Universal Decimal Classification

Copyright 1953 by the American Standards Association, Incorporated  
 70 East Forty-fifth Street, New York 17, N. Y.

Printed in U.S.A.  
 ASA15M453

Price, 25 Cents

#### **4. Preferred Track Position**

**4.1** Track No. 1 is the preferred position for 35mm single-track recording and is the standard position for 17½mm recording.

#### **5. Recording and Reproducing Speed**

**5.1** Recording and reproducing speed shall be 24 frames per second (see American Stand-

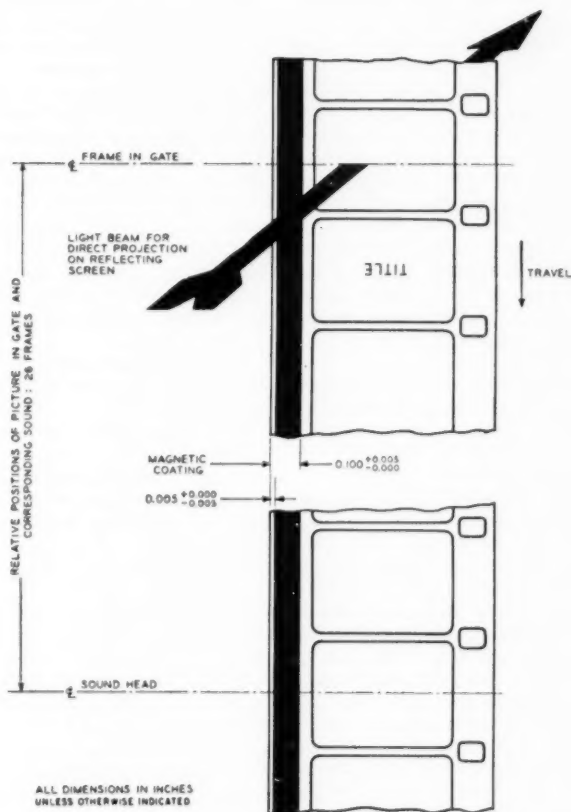
ard Emulsion and Sound Record Positions in Camera for 35mm Sound Motion Picture Film, Z22.2-1946, or any subsequent revision thereof approved by the American Standards Association, Incorporated [now being revised as PH22.2, 35mm Sound Motion-Picture Film—Usage in Camera]). This is exactly 96 perforations per second and approximately 18 inches per second.

PH22.86-1953

AMERICAN STANDARD

Dimensions for  
100-Mil Magnetic Coating  
on Single-Perforated 16mm Motion-Picture Film

ASA  
Am. U. S. Pat. Off.  
PH22.87-1953  
\*UDC 778.554.4



The magnetic coating in the above drawing is on the side of the film toward the lamp on a projector arranged for direct projection on a reflection-type screen.

The projection speed shall be 24 frames per second.

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[With a few of the immediate introductory remarks deleted, there follows the Get-Together Luncheon speech of the 73d Convention, given on April 27, 1953, by Mitchell Wolfson, motion-picture exhibitor and operator of Wometco Theatres, Miami, Florida.]

There is in literature an account of a creature which had the startling ability to fly off in all directions at one and the same moment, and yet not destroy itself as a whole. With regard to revised viewing techniques for motion pictures, I fear that we are trying to do the former, that is fly off in all directions, but with great danger of falling victim in the process.

Sometime, and you gentlemen know it far better than I, we shall emerge with the one best system for the improved showing of motion pictures, and it is my sincere hope that we do not have to wait for too long.

Please understand that in this portion of my comments I am dealing solely with 3-D, periphery viewing, or whatever technique may yet be for the improved viewing of motion pictures.

After standardization — and I want to put special emphasis on those words — *after standardization*, it would seem that our problems come in this order: First, we need an improved light source — greater and more even brilliance coupled with either an adequate cooling apparatus or film gates and film which can endure the greater temperature without harm. And an important part of this improved light is a power supply of sufficient capacity and reliability.

Second, we need a not-too-costly screen with a picture surface which will be compatible with both the new picture and films as we now know them. This screen must have the further qualification that it be suited to the structural limitations of most existing theaters. Of course, all these video improvements must be accompanied by stereophonic sound at a reasonable cost. And finally and most important, this stereo sound must be contained on a sound track which is placed on the same film print that includes the picture and which should continue to use 35mm stock.

And third, you who create must also educate. When you have accomplished standardization, adequate light and power, and suitable screens and sound, then you must embark on a widespread but simply worded educational program so that that to which you have given so much of yourselves does not suffer through misuse.

As a member of the motion picture industry, I for one am a little embarrassed that outside capital took techniques which we, for years, knew existed — and with them stampeded us into such precipitous action.

But mingled with embarrassment is a good measure of elevation over the fact that the industry is on the move. Apparently, we have quit wringing our hands in despair and are now using that energy to bring the motion picture up more fully to its potential.

While I am not absolutely certain as to the reasons why I was invited to speak here, I am sure that one of the reasons must have been that you wanted to know how exhibitors feel about all this. Frankly, gentlemen, we've been romanced, cajoled, wheedled, high-pressured, and in some measure I think confused as regards these new techniques.

What we want is to separate fact from fancy and the workable from the impractical. Our heads are spinning with the varied formulae being hurled at us. We hear of screen proportions of 4 to 3, 5 to 3, 6 to 3, and 8 to 3. On the heels of a supposedly authoritative announcement that the present 3-D is no good for drive-ins, we get word that drive-ins are actually experimenting with 3-D and are having some success. We get long distance phone calls urging us to call in engineers who, and I quote, "know all about the new process," and can survey our theaters and tell us just what we need. So we invite engineers to survey our theaters at our expense. What happens? They tell us they do *not* know anything about the new process, and would not know what to survey if they came to our theaters. They ask us to insist on standards.

We are urged to sign orders for equipment which others tell us does not exist.

Claims made by one group are refuted by another.

If all this sounds as though I am irked by these happenings please discard that thought. We may be confused but it is a happy confusion because, as I said before, it's a sign that the industry is on the move; that people in the industry are out to improve it and not just out to bring a lawsuit—which seems to have been the favorite pastime of the last decade. Happily for you gentlemen, that latter is a spectator sport as far as most of you are concerned.

There may be some in the industry who are egging you on with the "Hurray—hurray—hurray" of the circus barker. I urge more caution than this because we cannot afford to nor will we change our booth equipment and screen every time the picture changes. If we knew for a certainty now just what single technique would emerge as the best, I too would be urging all exhibitors to hurry. But we do not know.

Rather than dwell on what we do not know, let's line up in a row the ducks that we do know:

1. Well, the number one duck is a fact that you gentlemen touch on only in a technical manner and not professionally—that is the fact that a good show with mass appeal never goes wanting for an audience, regardless of the number of dimensions it is able to display.

2. Our number two duck is the fact that the interest of the public is stimulated by viewing methods which create more realism.

3. The number three duck is a twin brother of number two and lies in the belief that one, or a combination of the new methods of presenting motion pictures will arouse the public to a sustained interest in the industry in general and its product in particular.

There are our three ducks which will come first into our gun sights. And you can accuse me of a double meaning if I say that we are awaiting them in our blind.

I don't believe that any one of these ducks is going to be brought down with one blast of a gun. And that number three duck—the final improved method for showing our wares—is going to take

a lot more birdshot than any one of us can carry. But regardless of the number of shells which have to be used to get that duck, he's going to taste mighty good when we do bag him; and it will be a feast enjoyed by millions—you, me, and the public.

When first I was asked to address this convention, some months ago, one item high on the agenda was drive-in theaters. I imagine that all the talk and work on new picture sizes and viewing with stereo sound methods will, in the meantime, limit interest for awhile in these outdoor movies.

Nevertheless, they need some mention here, not only because the subject was in the original agenda, but because there are over 3600 drive-ins now grossing over \$200,000,000 yearly, and this is a specialized theater which draws, for the main part, from a specialized segment of the public, some of whom would not attend indoor theaters even if there were no drive-ins. It is for this reason that I believe that the new viewing methods and stereophonic sound are not as immediately important for these theaters.

Do not mistake me. These theaters constitute an important and vital part of our industry. Improvements are taking place in these theaters. I believe that the trend will be to the twin drive-in. The basic reason for this is a factor in which you are vitally interested and that is definition in the picture. With a twin, the drive-in need be only eight or nine ramps deep which permits practical viewing of a picture of sufficient size and clarity, and certain economies and better operations, such as one booth atop the concession stand; one concession stand to serve both sides of the twin drive-in and an opportunity in double-feature territory for the patron to select the picture he wants to see, by driving his car to that side of the twin which is exhibiting the particular feature that he wants to see. Yet a patron can remain in his car without moving and see the second feature if he cares to see both features.

While I foresee a continued general success for the drive-in theater with pictures as they have been made in the past, these showplaces do need a great measure of your skill to provide them with the new techniques. Most important, perhaps, is

that improved light source of which I spoke earlier. In fact, this is needed in many drive-ins today for today's picture.

Another point might be that you could further develop the process of rear projection which I have not yet seen but which is reported to allow shows to start earlier in the evening and which may solve other problems.

There is another item that costs this industry millions of dollars every year and which engineering might relieve to some extent. That is shipping charges on films. If the film itself cannot be made lighter, then surely in this day when synthetics are proving they can do many jobs better than the material they substituted for, the shipping cases can be made lighter and yet as durable.

I am most happy that your Society recognizes the kinship of motion pictures and television — even though some in our industry have not.

I have just come from some exhibitor meetings where I have urged their continued interest in, and work toward, the establishment of an effective theater-television system. I should do no less here. Theater-television can and will bring culture to Main Street and wider knowledge to the citizens of every town in the land. The revenue-producing potential of theater-television has not yet begun to be tapped, and in my opinion its importance has been overlooked by many. Week before last, Arthur Godfrey came to Miami to originate his telecasts from there. Theater business that week was normal to good every night but Wednesday. That was the night of his telecast from there and that was the night that our theaters, and our competitors' theaters, were empty.

That proves again the power of immediacy — which is the power of theater-television.

The mention of theater-television brings to mind the parallel characters of the motion-picture theater and of regular television broadcasting. As a businessman who has operated 35 theaters for nearly 30 years, and who also happens to own a television station, I would like to relate some of our experiences and some of our successes, which seem to prove that experience in one of these businesses serves to improve the other.

First, we have used and have seen the tremendous public response to movie advertising on television. TV advertising of movies is more than selling — it's compelling.

And it should cause no surprise to our way of thinking that we, theater owners, were the first to become television broadcasters in Florida. In both mediums, we are using a picture that shows movement combined with sound, and in both we are providing entertainment for the public. That one of these systems sells as it tells is an economic factor only; the premise remains the same. The surprise to me is that many other exhibitors did not pioneer television broadcasting. How well the two entertainment systems blend and may help each other is pointed out by one of our experiences. This happened a couple of years ago. As exhibitors used to a sharp clear picture, we were wholly dissatisfied with the picture we were getting from kinescopes and film on television. Our own research department went to work on that problem and before long had come up with a camera far superior to anything on the market — so good, in fact, that our TV viewers said that our kinescope shows were about as good quality as cable quality and we were asked by several other stations to build similar cameras for them. We believe this was a good contribution to the art of TV broadcasting resulting from our motion-picture experience.

Nor do we believe it was by chance alone that our television station, last year, was given by the National Association of Radio and Television News Broadcasters the top award in all the nation for our station's news coverage. Again, we attribute this success to our long experience with newsreels. As exhibitors, our experience and appreciation of the public interest in moving and talking newsreels in the theaters led to our awareness of this dynamic television news need and probably induced our willingness to spend the money to accomplish this gratifying recognition.

*Public service* — there's the watchword of both theaters and television; and it is more improved standards and contributions in this field which will bring more satisfaction and prosperity to all in either field. It will bring the public better entertainment, the men engaged in the

industries better salaries, and the stockholders better dividends. Public service has been a long-time ally of the successful motion-picture exhibitor. The local theater and theaterman has been the focal point in the community for Red Cross, Community Chest, War Bond and other patriotic and civic drives. He is long experienced in the community effort and could add greatly to the public service opportunities of television broadcasting.

You will note that I have not tried to prophesy the future of either 3-D, periphery vision or drive-in theaters, nor even TV; but of several facts I am sure. The

American public wants and will pay for better viewing techniques.

Our television and motion-picture industries await these new improvements in viewing, in color and in various dimensions.

We need you — the engineers — and look to you for these new and exciting opportunities. With the help of the various crafts and allied artists and their productions of good entertainment, I am sure that we businessmen can sell our combined efforts to the American public and the world with ever increasing benefits to all.

In business, just as in a locomotive, the engineer is the man up front. Guide us well, gentlemen.

## Letters to the Editor

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### Re: "Basic Principles of the Three-Dimensional Film"

[from H. Dewhurst]

In this most interesting paper by Raymond Spottiswoode, N. L. Spottiswoode and Charles Smith in the October 1952 *Journal*, the Authors appear to have singled me out by name as the pioneer protagonist of the "Human Vision" system of 3-D projection, about which they make criticisms which should not, I think, pass without challenge and on which, therefore, I feel I must take it upon myself to comment.

Otherwise, to my mind, the Authors are to be congratulated upon marked and positive contributions to the art of 3-D projection. They have, as it were, made a virtue out of expediency insofar as variable camera-lens interaxial spacing practice is concerned, in utilizing to the full the space in front of the screen; a forbidden ground hitherto which has tended to be regarded as taboo for all but stunt shots. An adjunct to this end which they have used — and a novel one as far as I know — is the placing in space in front of the screen of an aerial window, effected by marginal printing in the optical printer, enabling these in-front-of-the-screen shots to be viewed without eye strain. Their mathematical methods of analysis, too, cannot help but clear the air still further of current misconceptions, although I am a little dubious as to whether the lay mind will take readily to thinking

in terms of reciprocals. Their concept of a "nearness factor" does, however, provide a much needed reminder that an image placed, say, half-way in front of the screen for one viewer is half-way for all.

And now for my few complaints. In particular criticisms of fixed camera-lens interaxial "Natural Vision" systems, the validity of the arguments advanced by the Authors is to a large extent vitiated by the assumption, as in the introduction on page 276 to the "Part III" critique, that the lens-focusing mechanism is always coupled to the convergence control. As far as my own system is concerned, this is a misconception. I had thought to make it clear in my paper ("Auto-Precision Stereoscopy," *Phot. J., Sec. B. 92B*: 2-24, Jan.-Feb. 1952) that this coupling was normally in operation only when my attachment was used in conjunction with a stills miniature camera, and then only for instantaneous "candid" work — the coupling being subsidiary to an independent manual override.

Even with this restrictive complication of coupling left out, it is in any case a misconception for the Authors to say (p. 276): "It is therefore not to be expected that a mere reproduction at the camera of the human eye separation — in the absence of human viewing methods — will of itself produce strain-free viewing. This cannot

be so simply achieved until it becomes possible to create real or virtual 3-D images in space." No protagonist of an "interocular" camera-lens interaxial spacing, certainly not I anyway, would have said that a fixed interaxial had got anything whatever to do directly *per se* with strain-free viewing; it should be obvious from my own paper, which follows Prof. Rule's classic lead, that the conditions for strain-free viewing to which I adhere lie primarily and essentially in the avoidance of too marked a deviation from the normal convergence/accommodation ratio in viewing, and in the avoidance of divergence of infinity points in projection.

Elsewhere the Authors are very properly insistent upon the necessity of avoiding distortions. Throughout their argument it is not perhaps made obvious enough in their advocacy of a technique based on a variable interaxial that the onus of providing, in major part, the illusion of three dimensions in the majority of shots, is placed by them mainly upon the minor factor of convergence; nor, correspondingly, that their adoption of an interaxial camera-lens spacing of other than interocular must lead to the irrevocable recording of such disparate images on the film in the camera which, being once shot, cannot by any convergence or other means subsequently in the transmission procedure be made to give to the viewer that natural disparity between images which is the major and essential factor in a complete and lastingly convincing illusion of natural depth. This, to my mind, constitutes a major distortion which the advocates of a "Human-" or "Natural-Vision" fixed camera-lens interaxial spacing technique would I am sure regard as one which viewing audiences would not tolerate indefinitely.

However, my comments in the last paragraph above could be regarded as only an expression of a personal opinion and I would be far from expecting the Authors necessarily to agree with me, merely on my say-so! Clearly what is at issue here is the whole matter involved in the relative merits and demerits of techniques based mainly upon either a fixed or on a variable camera-lens interaxial or, if it comes to that, upon the fixed convergence technique of Dr. Reijnders as well. Such an issue cannot be much furthered by a mere exchange of letters and I hope that I may

find the opportunity to sustain at length in a considered paper the argument as it appears to one of the fixed-interaxial school of thought. In that event, nevertheless, I shall be hard put to it to equal the able manner in which the Authors have put forward their own.

H. Dewhurst  
Ministry of Supply  
Telecommunications Research  
Establishment  
Great Malvern  
Worcs., England

December 12, 1952

[from the Authors]

We appreciate Mr. Dewhurst's kind words about our paper, "Basic Principles of the 3-Dimensional Film," and feel that there is no fundamental difference of opinion between us, but rather a difference of approach. We are in full agreement that the vital requirements of strain-free viewing are careful control of the convergence/accommodation ratio presented to the spectator, and in particular the avoidance of divergence on background images. It is in order to meet these requirements under the conditions of studio shooting that we have developed our two-stage technique of careful measurement of the depth-range presented to the camera, and adjustment of the interaxial separation to keep the images within the strain-free range. The shot itself will on occasion need to be altered from that first proposed by the director, if the depth range it contains is too great to be compassed even at the minimum interaxial.

Mr. Dewhurst advocates that the retention of the images within the strain-free range be achieved without alteration of the lens separation from 2.5 in.; this it would be possible to achieve only at the cost of exercising far more drastic control of the permissible depth-content of the scene being filmed, and hence limitation of the freedom of expression available to the director. We feel that Mr. Dewhurst only regards this as the more desirable alternative because he is accustomed to working with very small magnifications where the depth-range limits during filming become proportionately less restrictive—the maximum screen size referred to in his paper is 21 inches only. If he were face to face with

the practical problems of producing studio films for exhibition on screens as many feet in width and more, we feel sure that he would rapidly recognize the advantages of using both the two possible means of controlling the parallax range on film which we have analyzed.

We are afraid we do not follow Mr. Dewhurst's reference to our reliance on "the minor factor of convergence." It is true that the convergence does not affect the reciprocal-unit depth-range embraced by the camera, which in our nomenclature is purely a function of the  $C$  factor ( $Mf_d$ ); but its action is no less than to govern the position in theater space at which the image as a whole is reproduced. We do not think that this can be described as "minor."

Perhaps we should make it clear that Mr. Dewhurst misrepresents us in referring to our insistence on the necessity of avoiding distortion. On the contrary, we point out that distortion will inevitably be present, as a perfectly orthostereoscopic image can at best be seen only by a single spec-

tator. What is important is that the cameraman shall have means available for assessing the amount of distortion present so that it shall not be permitted to exceed acceptable limits; and for this purpose we develop formulae for arriving at the depth magnification and width magnification of the image, which immediately give the required information. We certainly agree that the distortion introduced should be as small as possible compatible with the provision of strain-free viewing. Our whole procedure — based on an accurately controlled relationship between a variable convergence and interocular separation — has been devised to achieve these ends.

(the Authors)

Messrs. R. Spottiswoode, N. L.  
Spottiswoode and Mr. C.  
Smith  
Stereo Techniques, Ltd.  
36, Soho Square  
London, W. 1., England

April 3, 1953

## Current Literature

The Editors present for convenient reference a list of articles dealing with subjects cognate to motion picture engineering published in a number of selected journals. Photostatic or microfilm copies of articles in magazines that are available may be obtained from The Library of Congress, Washington, D.C., or from the New York Public Library, New York, N.Y., at prevailing rates.

### American Cinematographer

- vol. 34, Jan. 1953  
Set Lighting Innovations Mark the Photography of "5000 Fingers of Dr. T" (p. 16) *A. Rowan*  
Servo Mechanism for Remote Control of Mitchell BNC Lens and Finder (p. 18) *J. D. McCullough*  
vol. 34, Feb. 1953  
Stereo-cine Corporation is Newest 3-D Filming Organization (p. 60) *A. Rowan*  
"Fluid" Camera Gives Dramatic Emphasis to Cinematography (p. 63) *H. A. Lightman*  
A Built-in Exposure Calculator for Motion Picture Cameras (p. 68)  
What the Cine Photographer Should Know About Hyperfocal Distance (p. 70) *J. Walker*  
World's Largest 16mm Laboratory (p. 74)

- vol. 34, Mar. 1953  
Practical Filming Techniques for Three-Dimensional and Wide-Screen Motion Pictures (p. 107) *C. G. Clarke*  
All Hollywood Studios Shooting 3-D Films (p. 108) *A. Gavin*  
CinemaScope—What it is; How it Works (p. 112)

- Producers Service's 3-D Camera (p. 116)  
Magnetic Sound for Victor S.O.F. Projectors (p. 118) *J. Forbes*

### Audio Engineering

- vol. 37, Jan. 1953  
A Flexible Single Recording and Re-recording Channel (p. 28) *H. Magargle*  
Handbook of Sound Reproduction (p. 30) *E. M. Villchur*  
vol. 37, Feb. 1953  
Real Theater Sound in a Small Package (p. 19) *T. R. Hughes*  
The Wide Range R-C Oscillator (p. 21) *L. S. Goodfriend*  
Audio Transformer Design (p. 26) *N. H. Crouhurs*  
Distortion in Voltage Amplifiers (p. 28) *W. B. Bernard*  
Handbook of Sound Reproduction (p. 30) *E. M. Villchur*  
vol. 37, Mar. 1953  
Theater Sound in a Small Package (p. 30) *T. R. Hughes*

Handbook of Sound Reproduction, Chapter 10, Loudspeakers, Pt. I (p. 32) *E. M. Villchur*

vol. 37, Apr. 1953  
Theater Sound in a Small Package (p. 24) *T. R. Hughes*

An Auxiliary Mixer for TV Studios (p. 26) *G. A. Singer*

Handbook of Sound Reproduction, Chapter 10, Pt. II (p. 29) *E. M. Villchur*

#### **Bild und Ton**

vol. 5, Dec. 1952  
Übersichtstabelle über 16-mm-Bildprojektoren und-Bildtonanlagen (p. 376)

Die Dosenentwicklung von Agfacolorfilmen (p. 385) *H. Franke*

vol. 6, Jan. 1953  
Die Reibung des Films im Filmkanal von Kino-geräten (p. 4) *Frielinghaus*  
Der Sekundärelektronen-Vervielfacher in der Tonfilmtechnik (p. 9) *F. Eckart*

Übersichtstabelle über 16-mm-Bildprojektoren und-Bildtonanlagen (p. 16)

vol. 6, Feb. 1953  
Muss die Schärfe moderner Kleinbildobjektive verbessert werden? (p. 35) *H. Mehnert*  
Übersichtstabelle über 16-mm-Bildprojektoren und-Bildtonanlagen (p. 48)

#### **British Kinematography**

vol. 21, Dec. 1952  
Separation Negatives and Positives for Colour Films (p. 144) *G. W. Ashton and P. Jenkins*

vol. 22, Jan. 1953  
Standardization of Sound Quality on 16mm Re-lease Copies (p. 4) *N. Leavers*  
The B.B.C. Television Newsreel (p. 11) *P. H. Dorté*

vol. 22, Feb. 1953  
Review of Technical Developments in 1952 (p. 34)

#### **Electrical Communication**

vol. 29, Dec. 1952  
High-Gain Loop Antenna for Television Broad-casting (p. 268) *A. G. Kandoian, R. A. Felsenheld and W. Sichak*

#### **Electronic Engineering**

vol. 25, Mar. 1953  
Television Sound Reception. The Critical Cap-acitance Coupling System (p. 114) *S. L. Fife*

#### **Ideal Kinema**

vol. 18, Nov. 6, 1952  
Cinerama (p. 3) *L. Coulter*

#### **International Projectionist**

vol. 28, Jan. 1953  
Natural Vision—Another Step in the Right Direction (p. 5) *M. Chamberlin*

Some Technical Details of Natural Vision (p. 6)  
1952: A Wonder Year for Progress (p. 9) *L. Chadbourne*

Color Television Simplified by New Paramount Tube (p. 14)

Types of Theatre Sound Reproducers, Pt. I, The Sound-on-Disk Reproducer (p. 16) *R. A. Mitchell*

vol. 28, Feb. 1953  
Three-D Projection: Progress Report (p. 7) *M. Chamberlin*

Introducing "Modulation" (p. 14) *J. Behlke*  
Types of Theatre Sound Reproducers, Pt. II, The Variable Reluctance Pickup (p. 17) *R. A. Mitchell*

vol. 28, Mar. 1953  
Types of Theatre Sound Reproducers, Pt. III, The Sound-on-Film Reproducer (p. 5) *R. A. Mitchell*  
The Film-Cooling Problem (p. 10) *F. C. Matthews*  
3-D Projection Requisites: Motion Picture Re-search Council (p. 12)  
These "Curved" Screens (p. 16)

#### **Kino-Technik**

no. 1, Jan. 1953  
Über das Prinzip der Fernseh-Bildaufnahme-röhren (p. 12)  
Theorie und Praxis der Fernseh-Bildgestaltung (p. 14)  
Schmalfilm-Projektoren (p. 18) *H. Weise*  
Störungen bei der Vorführung von Tonfilmen (p. 19) *K. Braune and H. Tümmel*  
Der Tonfilmverstärker Dominar (p. 20) *M. F. Riedel*  
8-mm-Kameras auf dem deutschen Photomarkt (p. 23)

#### **Motion Picture Herald**

vol. 190, Jan. 10, 1953  
(Better Theatres Section)  
A Greater Theatrical Medium in the Making (p. 10)

vol. 190, Feb. 7, 1953  
(Better Theatres Section)  
How Faulty Sprocket Teeth Injure Film—Threaten Fire. (p. 45) *G. Gagliardi*  
**Motion Picture Herald**

vol. 190, Jan. 31, 1953  
Third Dimension and Its Cousins are Perched on Exhibition's Doorstep (p. 12) *G. Schutz*

vol. 190, Feb. 7, 1953  
The Story of 3-D from 1613 to 1953, Pt. I (p. 16) *M. Quigley, Jr.*

vol. 190, Feb. 21, 1953  
The Story of 3-D from 1613 to 1953, Pt. II (p. 14) *M. Quigley*

vol. 190, no. 12, Mar. 21, 1953  
20th-Fox Will Cast Its Lot With Cinemascope (p. 19) *W. R. Weaver*

### Philips Technical Review

vol. 14, Jan. 1953  
Magnetic Sound Recording Equipment (p. 181)  
*D. A. Snel*

### Photographic Engineering

vol. 3, no. 4, 1952  
Optical Attitude Recorder for the Aerobee Rocket (p.169) *G. Schweisinger*  
Some Current Image Converter Practice (p. 189)  
*R. F. Lawrence and K. Shaftan*  
Time Pulse Numbering System for 16mm Magazine Cameras (p.207) *R. C. Byers*  
A Semi-Automatic Data Reduction Device (p. 210) *F. D. Mason*

### Proceedings of the I.R.E.

vol. 41, Mar. 1953  
Generation of NTSC Color Signals (p. 338) *J. F. Fisher*  
Standards on Television: Definitions of Color Terms, Pt. I, 1953 (p. 344)

vol. 41, Apr. 1953  
Standards on Sound Recording and Reproducing Methods of Measurement of Noise, 1953: I.R.E. Standards Committee (p. 508)  
Transfer Characteristics and Mu Factor of Picture Tubes (p. 528) *K. Schlesinger*

### Tele-Tech

vol. 12, Apr. 1953  
A New Multiplex System for Three-Dimensional Sound (p. 92) *A. J. Forman*

## Book Reviews

### The Handbook of TV and Film Technique

By Charles W. Curran. Published (1953) by Pellegrini and Cudahy, 41 E. 50 St., New York 22, and George J. McLeod, Ltd., Toronto, Canada. 120 pp. (incl. 21 pp. glossary and 2 pp. index). Numerous charts and illustrations.  $5\frac{1}{2} \times 8\frac{1}{8}$  in. Price \$3.00.

This is a complete revision in book form of a multilithed booklet entitled, "The Handbook of Motion Picture Technique for Business Men," published in July 1952. It contains not only a general review of the actual steps in the production of a motion picture for industrial or TV use, but also considerable information on costs. It will be useful to all producers in dealing with clients and especially to the smaller production organizations. Reproductions of actual story boards alongside prints of the final scene, pages from an actual shooting script, tables of cost data and an illustration of the American Television Society Recommended Standard Contract Form all give practical information for the producer. While personal prejudices of the author are reflected in a few places (as in the glossary definition of "kinescope"), the book is very generally free of these. This is one of the best books of its kind this reviewer has seen.—*Gordon A. Chambers*, Eastman Kodak Co., Rochester 4, N.Y.

### Proceedings of the National Electronics Conference, Vol. 8

Published (1952) by National Electronics Conference, 852 E. 83 St., Chicago 19. 835 pp. incl. numerous charts, diagrams and tables, + 13 pp. cumulative index.  $6\frac{1}{4} \times 9\frac{1}{4}$  in. Price \$5.00.

The current volume contains the text of 97 technical papers and luncheon speeches presented at the 1952 Conference. Subjects include: antennas, the assembly and measurement of components, audio, circuits, coding and recording techniques, computers, delay lines and HF test equipment, electronic instruments, engineering management, industrial measurements, magnetic amplifiers, memory tubes, radar, radio navigation, reliability of components and equipment, semiconductors, servomechanisms, television, transistors, UHF transmitter, and waveguide.

In comparison with the previous volume, which contained many titles marked "Abstract only," all but one of the papers in the present volume are complete. This, together with an increase in the number of papers presented, has resulted in a volume approximately 100 pages larger than its predecessor. Indexing and organization of the subject matter are essentially the same as in previous volumes. Typography is clear and illustrations are very legible. There are a few typographical errors, which must be pardoned

on the basis of complete and rapid presentation of a huge mass of information while still fresh enough to be of value.

It would be presumptuous on the part of any one reviewer to pass on the technical adequacy of the papers presented. The volume represents a tremendous accumulation of information and experience in many fields of specialization. Few will read it in its entirety; but many will make use of selected articles in their particular fields of electronic technology.—*Bernard D. Plakun*, General Precision Laboratory, Inc., Pleasantville, N.Y.

### Color Fundamentals

By Maitland Graves. Published (1952) by McGraw-Hill, 330 W. 42d St., New York 36. i-xii + 206 pp.  $7\frac{1}{4} \times 9\frac{3}{4}$  in. Price \$10.00.

This is an elementary introduction to color by an able art teacher, but it is more than a textbook for art students. The apparent purpose of providing background and technique for artistic application of color is more than fulfilled. The beginner or general reader is treated to a fascinating though abbreviated account of the basic phases of color. The treatment starts logically with (1) the color stimulus or light which is followed by (2) light modifiers or colorants. Next comes (3) the eye and color sensation, then (4) color sensation modifiers including color blindness and contrast. The final section called (5) color organization, deals with the specification of artist's paints and the employment of harmonious color combinations.

This is an obviously psychological approach and it appears opportunely at a time when the physically-minded are coming to recognize the fuller significance of the appearance aspect of color. Even in this elementary account the author has been able to show how the deobjectification of color need present no insuperable obstacle to color measurement. Indeed, a feature of the book is a description of the Munsell System of color and its application to the problems of color harmony.

The unique contribution of Graves' work is a series of 100 harmonious color schemes of four colors all of which are shown in color. These color reproductions are quite indicative though admittedly

imperfect; however, anyone who mistrusts them will find the exact Munsell specifications printed adjacent to each of the 400 reproductions. Thus the Munsell colors themselves can be consulted either by reference to the Munsell Book of Color or by means of a convenient Color Cabinet described by the author. The principles of good color combinations are also discussed in the text. The attractiveness of the book is enhanced by numerous other illustrations both in color and black and white.

There are two rather serious omissions. Though after-images are described and demonstrated, there is no broader indication of the role of visual adaptation in color appearance; indeed, the whole subject of color constancy is neglected. This is serious because color constancy has such a profound influence on color appearance. The expression, "modes of appearance" is misused to refer to color blindness and contrast; but the modes of appearance in the usual connotation are omitted. Ways of perceiving such as surface, film, volume and illumination would seem to demand mention in this context.

Some of the minor inaccuracies are understandably unavoidable with the simplified exposition which was required to implement the author's purpose. Other such errors, however, either reflect the omissions mentioned above or must be ascribed to a common temptation, viz., to leave one's special field too far behind in one's effort to box the compass of color. Nevertheless, a valuable new book has been produced not only for the beginner, but for anyone concerned with harmonious color planning.—*S. M. Newhall*, Color Technology Div., Eastman Kodak Co., Rochester 4, N.Y.

### Internationale Bibliographie der Farbenlehre und Ihrer Grenzgebiete

By Manfred Richter. Published (1952) by "Musterschmidt" Wissenschaftlicher Verlag, Göttingen. i-xiii + 244 pp.  $5\frac{1}{4} \times 8$  in. Price about \$5.00.

This is an important technical bibliography of color science and allied topics which is limited to publications during

the period 1940-1949. The main listing is alphabetical by author and contains 1867 titles. Nearly all are references to journal articles; only 5% are books, monographs, tests or special reports.

There is also an alphabetical listing according to 438 subject headings (Schlagworten). Few references are classified under most of these headings but there are 12 headings under each of which more than 30 references are classified. English equivalents of these 12 are: paint technique, color photography, color blindness, general color information, color vision, color measurement, color metric, color vision testing, resistance to bleaching, spectrophotometry, pseudo-isochromatic charts and dyeing of textiles.

Since the bibliography is of world scope, an estimation of the contributions by country is of interest. The breakdown with respect to nationality or at least publication language, is as follows: 59% English, 31% German, 7% French, 2% Russian, and less than 1% for the rest.

The difficulty of securing really adequate coverage in an international bibliography of this character, even when limited to a 10-year period, may be suggested by a comparison. A 10% sampling indicated that the Richter bibliography is about 35% as large as one of the unpublished American bibliographies in the same period; and that the Richter bibliography

includes only about 20% of the same references. In other words, the American bibliography would itself be 15% larger if it included all of the Richter references. The breakdown by publication language differs in expected directions. Thus, whereas the Richter bibliography was estimated to be 59% English and 31% German, the English bibliography was 75% English and 15% German. The lack of agreement can be ascribed in part to the occurrence in this period of World War II; but language and geographical factors are always present.

Several features of the Richter bibliography which contribute to its usefulness seem worth noting. Many of the articles are accompanied by a brief abstract or characterizing statement. The Russian references are usually presented in German also. Each reference is accompanied by the corresponding Universal Decimal Classification number (German). There is a brief appendix or glossary for clarifying certain terms related to color metric.

All in all, this bibliography is a valuable and convenient source of references for workers on scientific and technical color problems. It is encouraging to note the "Nr. 1" on the title page with its implication of following volumes for future decades.—S. M. Newhall, Color Technology Div., Eastman Kodak Co., Rochester 4, N.Y.

## Central Section Meeting

The Section's Managers met on April 16 at 4:00 P.M. at Encyclopaedia Britannica Films Inc., in Wilmette. Besides the planning of future Section Meetings, the Managers reviewed the matter of members delinquent on their 1953 dues. A list of those members will be circulated among the Managers who will endeavor to remind Central Section delinquents that the Society cannot operate without dues.

Final plans were made for the May 21 and June 11 meetings and it was decided to hold a Regional Meeting on September 11 at Dayton, Ohio. Mrs. Jane Bernier, President of Synthetic Vision Corp., will handle details for the Dayton meeting.

The Section's General Meeting of April 14 convened at 8:00 P.M. on the sound stage at Encyclopaedia Britannica Films Studio. Dr. Brodshaug welcomed the SMPTE members, numbering about 100. A film, *Inflation*, produced by Mr. Bobbitt of EBF was exhibited. John J. Walker, Director of Technical Production for EBF, discussed the problems encountered by EBF in converting a theater into a sound film studio. The group also toured and inspected the entire studio and library facilities of EBF.—James L. Wassell, Secretary-Treasurer, Central Section, 247 E. Ontario St., Chicago 11, Ill.

## Obituaries



**Peter L. Shamray** died May 12, 1953, in Wadsworth Memorial Hospital, West Los Angeles, Calif. He was 59 years old. Associated for many years with the motion-picture industry, he had worked as a laboratory technician and superintendent with D. W. Griffith Co., Fine Arts Film Co., Triangle-Keystone Co. and the Majestic Moving Picture Co.

During World War I he served in the Signal Corps as a laboratory technician and cinematographer in France. In 1925 he was studio and production manager for H. C. Weaver Studios in Tacoma, Wash. He had been Technical Representative for du Pont Motion Picture Film since 1927. He was an active member of this Society since 1943 and was an Associate member of the American Society of Cinematographers.

**Kenneth Shaftan** was killed on April 4 in the crash near Washington, D.C., of a small chartered plane in which he was returning to New York with two business associates from a military consulting assignment. As a Commander, U.S. Naval Reserve, he was buried with full naval honors at the National Cemetery, Arlington, Va., on April 8. He was 33 years old.

After graduation from Columbia University, Mr. Shaftan completed extensive postgraduate work at New York University College of Engineering and Columbia Graduate School of Engineering.

Commissioned Ensign, U.S. Navy in 1942, he became Officer-In-Charge of the Photographic Group of the Bureau of Ships.

At the time of his death, he was Director of Photographic Instrumentation, J. A. Maurer, Inc., Long Island City, N.Y., a department which he had organized and directed. At the same time, he was Consultant to the Office of Naval Research and to the Research and Development Board, Department of Defense, Panel on Photography and Optics.

His greatest interest centered around photographic instrumentation. He had established and maintained a voluminous

file of facts and data relating to photographic instrumentation, technology and scientific photographic equipment and procedures. He had written many technical papers, all exceptionally well documented.

After becoming a member of the Society of Motion Picture and Television Engineers in February 1946, he advocated the use of still and motion-picture photography as a tool of industrial research and did intensive studies of the published literature in this field for the Society. His reports, "A Survey of High-Speed Motion Picture Photography" and "Progress in Photographic Instrumentation in 1950" were published in the May 1950 and the November 1951 issues of the *Journal*. He was also Chairman of the Society's Committee on Engineering and Technical Society Liaison.

He was President of the New York Chapter of the Society of Photographic Engineers, and was an active member and contributing author of *The American Physical Society*, *American Institute of Physics*, *Optical Society of America*, *Royal Photographic Society of Great Britain*, *Biological Photographic Association* and the *Photographic Society of America*.

# New Members

The following members have been added to the Society's rolls since those last published. The designations of grades are the same as those used in the 1952 MEMBERSHIP DIRECTORY.

Honorary (H)	Fellow (F)	Active (M)	Associate (A)	Student (S)
<b>Adams, M. Clay</b> , Television Film Director, National Broadcasting Co. <b>Mail:</b> Sullivan Rd., Goldens Bridge, N.Y. (M)				
<b>Ashley, M. J.</b> , Chief Laboratory Engineer, New Zealand National Film Unit. <b>Mail:</b> 127 Hobart St., Miramar, Wellington, New Zealand. (A)				
<b>Auld, John S.</b> , Chief Engineer, Signal Corps Mobile TV System. <b>Mail:</b> 55 Violet Ave., Mineola, N.Y. (M)				
<b>Baird-Smith, Frank, Jr.</b> , University of California at Los Angeles. <b>Mail:</b> 717 Malcolm Ave., Los Angeles 24, Calif. (S)				
<b>Baker, Edward R.</b> , Film Editor, United Productions of America. <b>Mail:</b> 4639 Lasheart Dr., La Canada, Calif. (A)				
<b>Baker, Leslie J.</b> , Sales Representative, W. J. German, Inc., 6700 Santa Monica Blvd., Hollywood, Calif. (A)				
<b>Bell, Harry</b> , Laboratory Technician, Twentieth Century-Fox Film Corp. <b>Mail:</b> 11580 Blix St., North Hollywood, Calif. (A)				
<b>Blackman, Ernest A.</b> , Cameraman, 81 High St., Danvers, Mass. (A)				
<b>Blunt, R. M.</b> , Physicist, University of Denver Industrial Research Institute. <b>Mail:</b> 2075 Ash St., Denver 7, Colo. (A)				
<b>Bolmen, Perce W.</b> , Manager, Brooks Photo Supplies. <b>Mail:</b> 200 Almond Ave., Los Altos, Calif. (A)				
<b>Brester, Walter A.</b> , Supervisor of Engineers, WTOP, Inc. <b>Mail:</b> 4825—16 St., N.E., Washington 17, D.C. (A)				
<b>Buescher, Robert E.</b> , Contact Engineer, Radio Corporation of America. <b>Mail:</b> 780 Bronx River Rd., Bronxville, N.Y. (A)				
<b>Burleyson, Garth</b> , Recordist, U.S. Naval Photographic Center. <b>Mail:</b> 401 Circle Ave., Takoma Park 12, Md. (A)				
<b>Byrnes, Stan</b> , Production Assistant, Louis G. Cowan, Inc. <b>Mail:</b> 901 Walton Ave., New York 52, N.Y. (A)				
<b>Chadwick, Melvin W.</b> , Projection Sound Engineer, Metro-Goldwyn-Mayer Studios, Culver City, Calif. (A)				
<b>Chamberlain, Gifford S.</b> , Assistant to Director, Studio Relations, Technicolor Motion Picture Corp., 6311 Romaine St., Hollywood 38, Calif. (A)				
<b>Cheng, Robert Kuo-Weng</b> , University of Southern California. <b>Mail:</b> 1141 W. Jefferson Blvd., Los Angeles 7, Calif. (S)				
<b>Collins, Daniel C.</b> , Vice-President, Westrex Corp. <b>Mail:</b> 17 Lord Kitchener Rd., New Rochelle, N.Y. (M)				
<b>Crawford, Robert V.</b> , Owner, Camera Craft, 6764 Lexington Ave., Hollywood 38, Calif. (A)				
<b>DeLisa, Muriel</b> , Technical Writer, 1735 N. Wilcox, Hollywood 28, Calif. (A)				
<b>Dixon, Royden J., Jr.</b> , Visual Information Specialist, U.S. Department of State. <b>Mail:</b> 2406—33rd St., S.E., Washington 20, D.C. (M)				
<b>Entler, James P.</b> , Assistant Sound Recording Engineer, Geo. W. Colburn Laboratory, Inc. <b>Mail:</b> 2432 Maple St., Franklin Park, Ill. (A)				
<b>Eskridge, Charles V.</b> , University of Southern California. <b>Mail:</b> 6651 W. Fifth St., Los Angeles 48, Calif. (S)				
<b>Ewing, Maxwell</b> , Production Supervisor, Plains Radio Broadcasting Co., KGNC-TV Radio Bldg., Amarillo, Tex. (A)				
<b>Fitzpatrick, John D.</b> , Television Engineer, Lighting Director, National Broadcasting Co. <b>Mail:</b> 307 W. 93 St., New York 25, N.Y. (A)				
<b>Fuchs, Theodore</b> , Teacher, Consulting Engineer, Northwestern University, N.U. Speech Bldg., Evanston, Ill. (A)				
<b>Gibson, Thomas R.</b> , Vice-President, W. J. German, Inc., 6040 North Pulaski Rd., Chicago 30, Ill. (M)				
<b>Goebel, Robert J.</b> , Electronic Instrumentation Engineer, Eclipse-Pioneer Div., Bendix Aviation Corp. <b>Mail:</b> P.O. Box 75, West Milford, N.J. (A)				
<b>Gordon, Sol</b> , Washington Square College. <b>Mail:</b> 867 Hegeman Ave., Brooklyn, N.Y. (S)				
<b>Gorsline, Anthony L.</b> , University of California at Los Angeles. <b>Mail:</b> 2626 Portland St., Los Angeles 7, Calif. (S)				
<b>Greenwood, E. W.</b> , Armament Research, Canadian Armament Research and Development Establishment. <b>Mail:</b> Val St. Michel, Quebec, Canada. (M)				
<b>Gross, Robert</b> , Motion-Picture Producer and Writer, American Film Producers, 1600 Broadway, New York 19, N.Y. (M)				
<b>Gulley, William E.</b> , Director-Cameraman, Communications Center, University of North Carolina, Chapel Hill, N.C. (A)				
<b>Hageman, Theodore C.</b> , Partner, Owner, 5631 Hollywood Blvd., Los Angeles, Calif. (A)				
<b>Harris, Grant D.</b> , Motion-Picture Producer, Impact Production Associates, 5746 Sunset Blvd., Los Angeles, Calif. (A)				
<b>Hassim, Eusuph M.</b> , Managing Director, Lyric Cinemas, Pty., Ltd. <b>Mail:</b> P.O. Box 6002, Johannesburg, South Africa. (A)				
<b>Heward, Frederick R.</b> , Sale, Service and Design of Photographic Equipment. <b>Mail:</b> 3028 Del Monte, San Mateo, Calif. (A)				

- Hill, Edmund Clement**, Technical Director, Newman & Sinclair, Ltd. **Mail:** 258 Princes Ave., London, N. 13, England. (A)
- Hoffberg, William A.**, Consulting Engineer, 49 W. 44 St., New York 36, N.Y. (M)
- Hood, Franklin D.**, Electronic Engineer, Tektronix, Inc. **Mail:** 1315 N.E. Roselawn St., Portland 11, Ore. (A)
- Hugh, Albert Cecil**, Company Director and General Manager, Clarks Cereal Products, Ltd. **Mail:** Brook Barns, Chigwell, Essex, England. (A)
- Hughes, Daniel W.**, Motion-Picture Film Editor and Director, U.S. Department of Agriculture. **Mail:** 15 Black Hawk Dr., Forest Heights, Md. (A)
- Ilharmo, Joe**, University of Southern California. **Mail:** P.O. Box 16502, Hollywood 38. (S)
- Ishimaru, Stone S.**, University of Southern California. **Mail:** 3012 E. Second St., Los Angeles, Calif. (S)
- Johnston, Ned A.**, Film Technician, Acme Film Laboratory. **Mail:** 153 S. Bowling Green Way, Los Angeles, Calif. (A)
- Joist, John**, Sound Engineer, Film Div., United Broadcasting Co. **Mail:** 1501 N. Bell Ave., Chicago 22, Ill. (A)
- Kaplan, Sam H.**, Research Engineer, Rauland Corp. **Mail:** 3713 W. Arthington St., Chicago 24, Ill. (A)
- Klink, Granville, Jr.**, Chief Engineer, WTOP, Inc., Warner Bldg., Washington 4, D.C. (A)
- Kowalak, John J.**, Technical Representative, Ansco Div., General Aniline and Film Corp., 6424 Santa Monica Blvd., Hollywood, Calif. (A)
- Layos, Mrs. Albert J.**, Sound Recording, Cinesound Co., 5968 Santa Monica Blvd., Hollywood 38, Calif. (A)
- Lee, Ralph Frank**, Chief Engineer, Caprock Broadcasting Co., KCBD-TV, 1803 Broadway, Lubbock, Tex. (M)
- Lerpac, Paul K.**, Director of Photography, Paramount Pictures, Inc., 5451 Marathon St., Hollywood 38, Calif. (A)
- Lesser, Mort L.**, Slide Film Producer, Lesser Studio. **Mail:** 112 Grange Ave., Toronto, Ontario, Canada. (A)
- Levin, Harry**, Purchasing Agent, Federal Manufacturing & Engineering Corp. **Mail:** 238 Keap St., Brooklyn 11, N.Y. (A)
- Lipton, Sidney M.**, Mechanical Engineer, Ballistic Research Laboratories, Aberdeen Proving Ground. **Mail:** 106 Seneca Ave., Havre de Grace, Md. (A)
- Macdonald, Neal L.**, Professional Scouting, Boy Scouts of America. **Mail:** 330 Speedwell Ave., Morristown, N.J. (A)
- Marceau, Jules P.**, Manager, Southern Canada Power Co., Ltd., P.O. Box 430, Drummondville, Quebec, Canada. (M)
- Maynard, Gordon G.**, Film Technician, Technicolor Motion-Picture Corp., 6311 Romaine, Hollywood 38, Calif. (A)
- McConnell, Geo. L.**, Motion-Picture Photographer, Edwards Air Force Base. **Mail:** 14-17 St., Edwards, Calif. (A)
- McFarland, Richard E.**, Photographer, U.S. Navy Electronics Laboratory. **Mail:** 3853 Winona Ave., San Diego 5, Calif. (A)
- McKay, Douglas A.**, Assistant Cameraman, National Film Board, John and Sussex Streets, Ottawa, Ontario, Canada. (A)
- Mehrer, Gene**, Film Laboratory Technician, DeLuxe Laboratories, Inc. **Mail:** 26-16 Union St., New York, N.Y. (M)
- Merli, Armando**, Draftsman, Federal Manufacturing & Engineering Corp. **Mail:** 277 Seventh St., Brooklyn 15, N.Y. (A)
- Meyer, Louis F.**, Motion-Picture Cameraman, Northrup Aircraft, Inc. **Mail:** 12917 Valley Heart Dr., North Hollywood, Calif. (A)
- Minor, Fred J., Jr.**, Theatre Manager, Florida State Theatres, Inc., State Theatre, Gainesville, Fla. (A)
- Morgan, Wolcott V.**, Section Supervisor in Charge of Motion-Picture Studio, Eastman Kodak Co. **Mail:** Plank Rd., Macedon, N.Y. (A)
- Moriarity, Jack L.**, Film Editor, Geo. W. Colburn Laboratory, Inc., 164 N. Wacker Dr., Chicago 6, Ill. (A)
- Morrison, Rita**, University of California at Los Angeles. **Mail:** 7012 La Presa Dr., Hollywood 28, Calif. (S)
- Nelson, Arvid W.**, Motion-Picture Film Editor, Geo. W. Colburn Laboratory, Inc. **Mail:** 629 Edgewood Rd., Lombard, Ill. (A)
- Nemeth, Ernest S.**, Animation Photographer, 6260 Romaine St. Hollywood, Calif. (A)
- Nye, Clarence L.**, University of Southern California. **Mail:** 611 S. Westmoreland Ave., Los Angeles, Calif. (S)
- Onaka, Harry H.**, Columbia University, Teachers College. **Mail:** 411 W. 115 St., New York 25, N.Y. (S)
- Poppele, Arthur G.**, Television Engineer, National Broadcasting Co., 30 Rockefeller Plaza, Rm. 501, New York, N.Y. (M)
- Rogaway, J. Roy**, University of Southern California. **Mail:** 101 N. Gardner, Los Angeles, Calif. (S)
- Ruttencutter, Frank**, University of Southern California. **Mail:** 2636 Portland St., Los Angeles 7, Calif. (S)
- Rybnick, Harry L.**, Producer, Distributor, Jewell Enterprises. **Mail:** 6614 Van Noord Ave., North Hollywood, Calif. (A)
- Rydz, John S.**, Engineer, Color Correction Engineering Group, RCA Victor Division. **Mail:** Apt. 42A, Parkway Apts., Haddonfield, N.J. (A)
- Saint Georges, Julien**, Cameraman, C.B.C. Television. **Mail:** 2024 Marie-Anne St., East, Montreal 34, Canada. (A)
- Schlein, Samuel R.**, Production Manager, DeLuxe Laboratories, Inc. **Mail:** 22 Metropolitan Oval, Bronx 62, N.Y. (A)

**Scott, Walter H., Jr.**, Sound Recording Engineer, U.S. Naval Ordnance Test Station. **Mail:** P.O. Box 115, China Lake, Calif. (A)  
**Simmons, Albert H.**, Technical Executive, Gevaert (Canada), Ltd. **Mail:** 2263 Midway Ave. (Woodroffe), Ottawa, Canada. (A)  
**Slade, William A.**, Motion-Picture Editor, U.S. Air Force. **Mail:** 6043-22 Rd., North, Arlington, Va. (A)  
**Snyder, Ross H.**, Application Engineer, Magnetic Recorders, Ampex Electric Corp. **Mail:** 1021 Cotter Way, Hayward, Calif. (A)  
**Stolle, Walter F.**, Quality Control Engineer, Eastman Kodak Co. **Mail:** 528 Colebrook Dr., Rochester, N.Y. (A)  
**Sultanoff, Morton**, Research Engineer, Ballistics Research Laboratory, Aberdeen Proving Ground. **Mail:** 32 Aberdeen Ave., Aberdeen, Md. (A)  
**Thomas, William R.**, Los Angeles City College. **Mail:** 7104 Balboa Blvd., Van Nuys, Calif. (S)  
**Tribble, Robert H.**, TV Technician, National Broadcasting Co., Sunset & Vine Streets, Hollywood 28, Calif. (A)  
**Troxel, Clayton C.**, Projection Engineer,

Loew's, Inc. **Mail:** 1126 Galloway St., Pacific Palisades, Calif. (A)  
**Tusler, Theodore H.**, Photographic Supply Merchant, Alvin's Photo Supply. **Mail:** 201 S. Holliston Ave., Pasadena 5, Calif. (A)  
**Verdeckberg, Robert A.**, University of Southern California. **Mail:** 721 W. Thirtieth St., Los Angeles, Calif. (S)  
**Wade, Edward P.**, Technicolor Technician, Technicolor Motion Picture Corp. **Mail:** 5162 Melrose Ave., Hollywood, Calif. (A)  
**Walker, Jean L.**, University of Southern California. **Mail:** 707 S. Norton Ave., Los Angeles 5, Calif. (S)  
**Warren, Everett A.**, Director, Audio-Visual Center, Notre Dame University, 221 Main Bldg., Notre Dame, Ind. (A)  
**Weinberger, Isaak**, Head of I. Weinberger, Grabenwies 2, Zurich, Switzerland. (A)  
**Wester, Arnold J.**, Executive, Producer, Director, William Esty Advertising Co., Inc., 6331 Hollywood Blvd., Hollywood 28, Calif. (A)  
**Wilkinson, Lawrence A.**, Television Engineer, WTOP-TV, Warner Bldg., Washington 4, D.C. (A)

## Meetings

American Physical Society, June 18-20, Rochester, N.Y.

American Institute of Electrical Engineers, Summer General Meeting, June 29-July 3, Atlantic City, N.J.

PSA Convention (Photographic Society of America), includes a "Color Round Table" sponsored by the PSA Technical and Color Divisions, Aug. 3-8, Biltmore Hotel, Los Angeles

WESCON (Western Electronic Show & Convention), Aug. 19-21, Civic Auditorium, San Francisco

Biological Photographic Association, 23d Annual Meeting, Aug. 31-Sept. 3, Hotel Statler, Los Angeles, Calif.

Illuminating Engineering Society, National Technical Conference, Sept. 14-18, Hotel Commodore, New York, N.Y.

The Royal Photographic Society's Centenary, International Conference on the Science and Applications of Photography, Sept. 19-25, London, England

National Electronics Conference, 9th Annual Conference, Sept. 28-30, Hotel Sherman, Chicago

**74th Semiannual Convention of the SMPTE, Oct. 5-9, Hotel Statler, New York.**

Audio Engineering Society, Fifth Annual Convention, Oct. 14-17, Hotel New Yorker, New York, N.Y.

Theatre Equipment and Supply Manufacturers' Association Convention (in conjunction with Theatre Equipment Dealers' Association and Theatre Owners of America), Oct. 31-Nov. 4, Conrad Hilton Hotel, Chicago, Ill.

Theatre Owners of America, Annual Convention and Trade Show, Nov. 1-5, Chicago, Ill.

National Electrical Manufacturers Association, Nov. 9-12 Haddon Hall Hotel, Atlantic City, N.J.

**75th Semiannual Convention of the SMPTE, May 3-7, 1954, Hotel Statler, Washington, D.C.**

**76th Semiannual Convention of the SMPTE, Oct. 18-22, 1954 (next year), Ambassador Hotel, Los Angeles**

# Employment Service

These notices are published for the service of the membership and the field. They are inserted for three months, and there is no charge to the member.

## Positions Available

**Wanted: Motion-picture processing technicians** for employment at U.S. Naval Ordnance Test Station, China Lake, Calif. Operators of Models 10 and 20 Houston motion-picture processing machines, and operators of Bell & Howell Models "D" and "J" motion-picture printers are needed. Civil Service positions — \$3,410 per annum base pay. Family housing limited; single persons preferred. Obtain Form 57 from any U.S. Post Office, fill out in detail, and mail to Carlos H. Elmer, 410B Forrestal, China Lake, Calif.

**Senior Engineer** with leading supplier of motion-picture and TV equipment is looking for an associate in the development of film and tape handling equipment and other fine electromechanical devices. Give résumé of professional experience and range of interest and accomplishments by letter to W. R. Isom, 1203 Collings Ave., Oaklyn, N.J.

**Wanted: Two design engineers**, must be familiar with camera and precision instrument design. A working knowledge of machine shop practice essential. Salaries commensurate with ability. Send résumé of experience and personal details in letter to: Land-Air Inc., 900 Pennsylvania Ave., Alamogordo, N.M.

**Wanted: Cameraman-Director**, young man free to travel, to work in Southern states. Must be able to show sample footage. Send résumé of experience and personal details in letter. Address replies to P.O. Box 1531, Louisville, Ky.

**Career Opportunity in Midwest:** for competent photographer and cinematographer experienced in 16mm production techniques to become permanently associated, as working partner, with well established, financially responsible company producing medical and scientific films exclusively. Must be under 40, of excellent character, good personality and educational back-

ground. Write, stating age, education, experience, history of employment, marital status, salary expected and where confidential correspondence can be addressed. —Mervin W. LaRue, Inc., 159 E. Chicago Ave., Chicago 11, Ill.

## Positions Wanted

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